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CONTENTS

THE IRON AND STEEL INSTITUTE

Presidential Address
Social Consequences of Iron and Steel by R. G. Lyttelton 201
The Strain-Ageing of Mild Steel: A Critical Investigation of the Ageing of Mild-Steel Strip after Temper-Rolling
by B. Jones and R. A. Owen-Barnett 209
Electron Micrographs of Crystal Boundary and Sub-Boundary Structures in Steels and Ingot Irons by E. W. Williams and H. O'Neill 224

DISCUSSION ON PAPERS

Correspondence on Metallic and Non-Metallic Coatings 246
Correspondence on Temper-Brittleness 246

LETTER TO THE EDITOR

The Corrosion Potential of Stainless Steels During Stress Corrosion
by T. P. Hoar and J. G. Hines 248

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

A Method of Automatic Control for Sinter-Plant Feeder Tables
by S. K. Dean, W. N. Jenkins, P. K. Gledhill, and A. J. Blanchard 220
The British Iron and Steel Research Association: Sketty Hall, Swansea 229
A Combustion Method for the Determination of Sulphur in Slag
by the Methods of Analysis Committee 233
An Investigation of the Combustion Method of Sulphur Determination in Ferro-Alloys and Complex Steels
by the Methods of Analysis Committee 239
Determination of Silica in Blast-Furnace Slags
by the Methods of Analysis Committee 243

IRON AND STEEL ENGINEERS GROUP

Discussion on Manipulating Equipment, Guides, Guards, and Strippers for Rolling Mills 249

NEWS

The Iron and Steel Institute ... 256
News of Members 257
Contributors to the Journal ... 257
British Iron and Steel Research Association 257
News of Science and Industry 258
Diary 260
Translation Service 260

ABSTRACTS

Contents 261
Abstracts 261-292
Book Notices 292
New Publications 295

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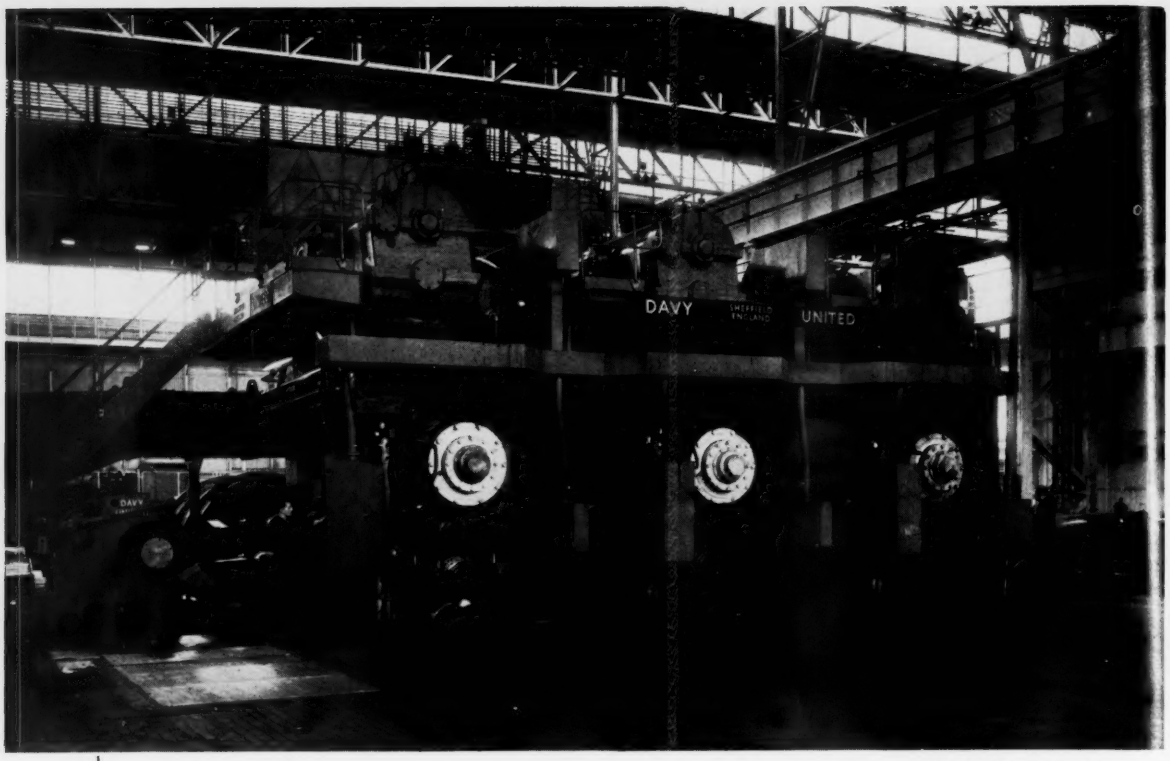

80" wide 3-Stand Tandem Mill, in the Abbey Works of The Steel Company of Wales. This mill rolls mild steel strip from 40,000 lb. coils in widths up to 74" at 2,035 feet per minute.

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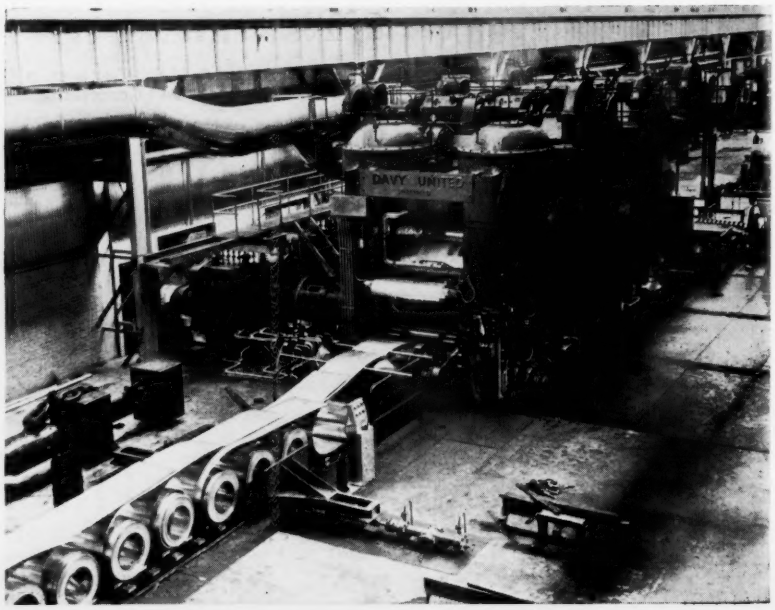

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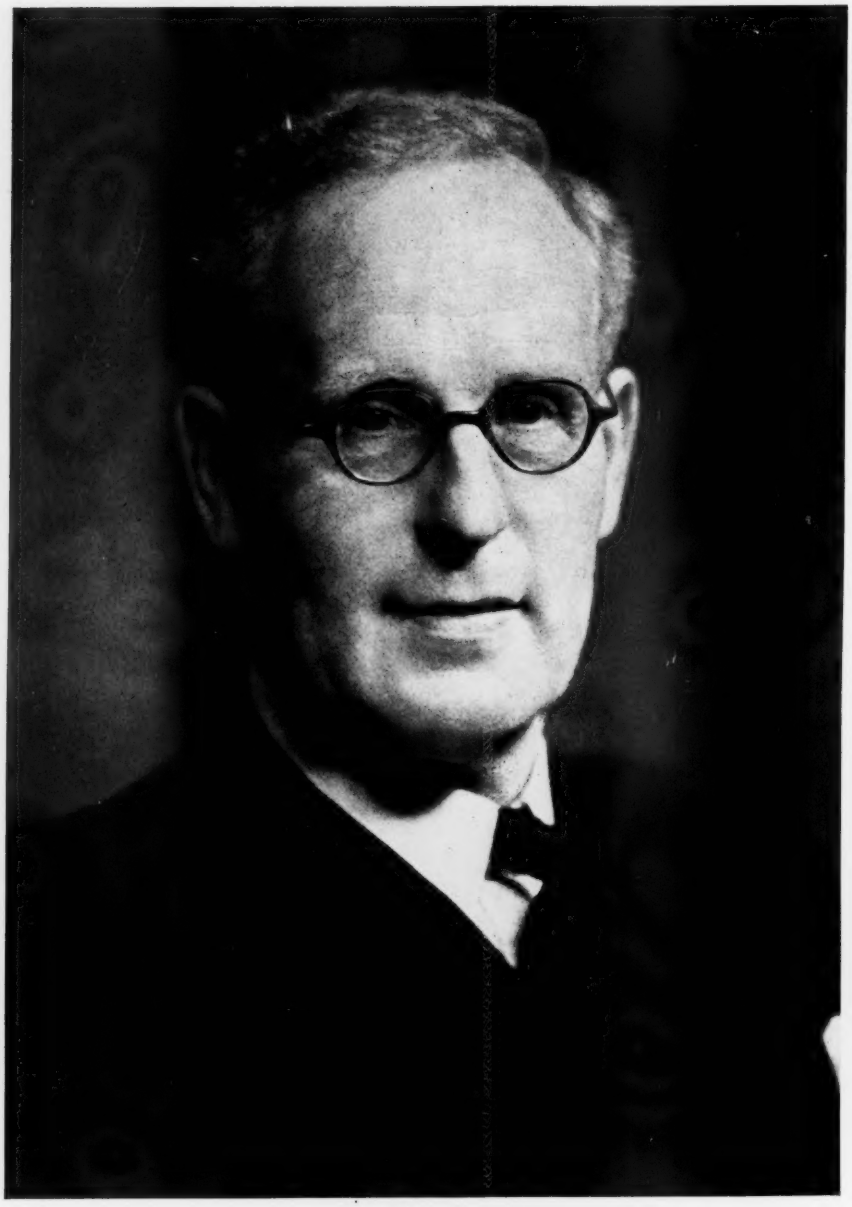
RICHARD GLYNNE LYTTELTON

RICHARD LYTTELTON was born in 1893 at Hagley, near Halesowen, Worcestershire. It was here that an iron furnace or bloomsmithy was erected between 1602 and 1606 by his ancestor, Meriel Lyttelton, and her son Thomas, which finally closed down in 1772.

He served throughout the First World War in the First North Midland Territorial Division in France, and until recently was Honorary Colonel in the Territorial Army.

Mr. Lyttelton joined Guest Keen and Nettlefolds Limited in 1919. He was engaged at various works, including Rogerstone, Dowlais, Scunthorpe, and at Bilbao, before going to the London office of the G.K.N. Group of Companies in 1928. He is a Director of Guest Keen Baldwins Iron and Steel Company, Limited, and other Companies.

He joined The Iron and Steel Institute in 1920. He became Honorary Treasurer of the Institute in 1941 and was elected a Vice-President in 1948. He took office as President at the Spring Meeting of the Institute on 26th May, 1954.



The Hon. R. G. Lyttelton
President, 1954-55

PRESIDENTIAL ADDRESS

THE IRON AND STEEL INSTITUTE

Social Consequences of Iron and Steel

By R. G. Lyttelton

I am deeply sensible both of the honour and of my own inadequacy in being invited to occupy this chair where so many great men have presided in years past, and thank you for that honour.

In addressing you on some of the social consequences of iron and steel I claim nothing original. But I feel that an attempt should be made, if only in outline, to relate the various stages of development of the industry to the social and material development of mankind, and particularly in the United Kingdom. It has been well said that people cannot look forward to posterity who never look backwards to their ancestors.

THE industrial history of mankind may be divided into two major epochs—a Stone Age, and a Metal Age. *Homo sapiens* is believed to have flourished for at least 500,000 years, and to have inhabited Europe for some 50,000 years. The Age of Metal, from existing evidence, commenced about 7000 years ago, only a very small fraction of the period of the life of man.

Civilization as we know it could not begin until metals became available as material for tools, implements, and machines. Until the advent of metals a society had emerged based on the enslavement of the many ministering to the luxury of the few.

It was the discovery of iron which gave the great impetus in early times to the development of man both intellectually and materially. No other single element has exercised such a profound influence on the social organization of mankind. Today, directly or indirectly, iron enters into every moment of our lives, sleeping or waking. At the same time it cannot be claimed that iron was the dominant influence in the first emergence of man from primeval barbarism.

The neolithic cultures of the new Stone Age, based upon the desire for mutual protection and the invention of the plough, achieved a considerable degree of urbanization. Thus, the division of labour occurred long before the discovery of metals. The first use of metal, by increasing substantially the productive power of human effort both in agriculture and in war, developed the new civilizations and social orders. These latter had evolved some centuries before without the aid of iron. With these developments man became converted from a hunter to a farmer, from a food gatherer to a food producer, and he was prompted to found settlements in districts where metals were available. The early communities of farmers gathered along the edge of the Nile and in Syria before 4500 B.C., and here urban civilization was initiated without the help of iron; but the development of urbanization to its present stage would have been impossible without transport, both road and rail, and communications, which iron and steel alone made possible. The technique of smelting and of the fashioning of metal into arms and tools was similar throughout the known world of the period, a fact which suggests its origin at one centre.

Doubtless, minor differences to meet local needs were slowly introduced in different centres, and where these marked an improvement they ultimately became—through the interchange of people and products between different communities and countries—more widely adopted. Through this interchange, on the basis of barter, trade was born.

Iron tools for wood working and for agriculture increased production in both occupations for the same expenditure of human effort. The first capitalist thus accumulated, to begin with, stores of grain and then more and more tools. As early as the fourth century

the iron horseshoe was introduced—an invaluable adjunct, which not only adapted the horse for work in places other than grass lands but greatly increased his pulling power.

EARLY IRON

The earliest iron remains are now accepted as being of meteoric origin. Meteoric iron was known over a considerable area of the ancient world. This is made evident by the traditional name for iron in many languages, which, when translated, means " something hard from heaven." A pyramid inscription of 2500 B.C. calls it " metal of heaven," whilst a Hittite text eleven hundred years later mentions " black iron from the sky," thereby indicating the colour of the surface of meteoric iron. The Aztecs of Mexico produced knives and daggers from meteoric iron, which they valued far above their gold. In answer to their Spanish conquerors as to where they obtained these pieces of metal they said they were gifts from the gods and came from the sky.

It is curious that in the Western world for many centuries meteoric iron was dismissed as mythical. It was not until April, 1803, when a shower of meteorites was observed at L'Aigle in Normandy by some thousands of people, that the celestial origin of this material was generally accepted. Meteoric iron contains anything from 3 to 7% of nickel, as well as traces of cobalt and other elements, which no doubt explains why some knives, beads, etc., made of it retaining their original form have been discovered after lying in the ground for some thousands of years.

The earliest known iron tool is a sickle discovered in the temple of Karnak and made in about 3000 B.C., and it is of interest that it was not until the 1890's, with the discovery of alloy steels, that steel of similar properties was produced by man—5000 years after the time when it was first used.

The beginning of the Iron Age is generally fixed at about 1400 B.C., and the earliest centre of production is now considered to have been Asia Minor, between the Caucasus and the Taurus Mountains, where the Hittites used lake and bog ores as well as iron sand, and wood for smelting. The products of this settlement were no doubt carried west, and the famous cemetery of Halstadt produces evidence of the iron industry of Carinthia, in 1000 B.C. It may be a matter of surprise that the Iron Age did not open earlier, when it is remembered that every ton of the earth's crust contains 1 cwt. of iron of a varying degree of purity: but the temperature required for reducing it from the ore is so much greater than in the case of copper and bronze that when iron ore was first subjected accidentally to the temperatures of the camp fire it was only reduced to the plastic state and was thought to be a malleable stone. The accidental appearance of this metal would need to happen many times before primitive man could notice it or connect the effect of heat with the occurrence of fusibility, and even then deduction from effect to cause might not be made.

It seems certain that metal working was introduced into Britain by immigrants from the Continent. Iron in the plastic state when hammered into shape by the squeezing out of slag revealed itself as a metal. From the primitive furnace—simply a hole in the ground in which alternate layers of ore and charcoal were laid — was developed the furnace made of puddled clay as a structure above the ground.

Iron is still produced by the natives of India, East Africa, the Kikuyu, and the Sudanese, in furnaces of this primitive character. The iron workers travel from one community to another, setting up temporary furnaces with local materials to produce iron in exchange for the products of the communities they visit. This method of producing iron persisted in Europe until the middle of the fourteenth century, the only advance being in the gradual enlargement of the furnaces. The iron produced was a plastic lump, the furnaces being called " bloomeries " from the Anglo-Saxon '*bloma*'—a lump. It was purified by reheating and continual hammering to squeeze out the slag and was, in fact, what is now known as wrought iron. This iron was too costly for general use except in a very limited way, mainly for service in war, but iron pots, spits, and frying pans, in the reign of Edward III, even in the fourteenth century, were classed among the Crown Jewels, though these may have been of special and elaborate fabrication. The frequent heating in charcoal fires for forging carburized the iron and occasionally produced weapons such as swords which, when quenched for cooling, became tempered steel. Thus arose the legends of swords with miraculous powers possessed by such heroes as King Arthur and Charlemagne.

INTRODUCTION OF MECHANICAL POWER

With the development of goatskin bellows operated by the feet of the workers, an artificial draught and a much higher temperature were obtained. There is evidence that bellows moved by water power were employed in the iron industry in very early times. The ancient world had made little or no attempt to obtain mechanical power, because of the inability of man to experiment, or even to observe natural phenomena; their reasoning was almost wholly speculative, unchecked by experiment or observation.

Although water power had long been used in this country, 5000 water mills for grinding corn being recorded in Domesday Book, no great development of mechanical power took place until the middle of the eighteenth century. The civilizations of Greece and Rome, being dependent upon slave labour, probably collapsed through lack of mechanical power to maintain the material demands of the luxurious social structure which they had created. Slave labour by itself was never sufficient to permit any great accumulation of national wealth, and consequently capital reserves were in chronic short supply. A computation has been made that the United States uses the equivalent in mechanical power of 27 slaves per head of population, and the United Kingdom about 14.

No real attempt was made in those days to accumulate wealth in reproductive form. Gradually, therefore, the standard of life from the second century A.D. onwards began to deteriorate; taxation increased, production decreased relative to population, and the whole apparatus of State began to falter until the ultimate collapse. When Rome was submerged by the tide of barbarism the existing structure of civilization

in Europe was demolished. For centuries after this great catastrophe the arts and manufactures, including ironmaking, largely fell into abeyance, although the Church, through the monastic establishments, preserved the knowledge and practice of agriculture and the arts. The individual once again became dependent to a great extent on his own production for all his needs.

BRITISH IRON INDUSTRY

It was not until the application of the water wheel to operate the bellows, *ca.* 1340, that cast iron was produced in Great Britain, almost certainly first in Sussex, where at Burwash there is a cast-iron tomb bearing an inscription in Lombardic characters of the fourteenth century. Some historians now ascribe this grave-slab to the sixteenth century. There was thus a period of 2500 years between the discovery of sponge iron and the art of casting it.

The iron industry in Britain developed largely in Kent, Surrey, and Sussex, owing to the presence of hardwood forests which provided the charcoal. The foundry industries of these counties, and of Sussex in particular, became famous for the production of cast-iron cannon, for which there was a considerable export trade. There is a record that Sir Thomas Shirley sold quantities to the Spaniards, and the pirates frequenting the English Channel were substantial customers. In the reign of Queen Elizabeth I the importance of the Navy for the protection of this country gave rise to alarm that the reserves of timber for ship-building were being denuded to a dangerous extent in the production of iron. Accordingly, the use of charcoal was prohibited in 1585 and by extensive legislation throughout the sixteenth century. The needs of the country for iron were supplied by importation, principally from Sweden and Virginia. From 1640 the iron industry in Britain suffered a steady decline, the records showing that whilst in 1665 there were some 150 furnaces in operation, by 1717 the number had been reduced to 59.

An ancestor of my own, Sir John Lyttelton de Frankeley, purchased the Manor of Hales in 1558, which included the " bloomsmithy " of Halesowen, originally erected by Thomas Faber (*i.e.*, Smith) in 1276. In 1602 it was not valued in a Census, so presumably it was not then producing. Between 1602 and 1606 a furnace was erected there by Meriel Lyttelton and her son Thomas, which was finally closed down in 1772. So that after an interval of some 150 years I have, in some measure, restored a family tradition.

In the early years of the eighteenth century Abram Darby, at Coalbrookdale, was experimenting with the use of stone coal in the production of iron. He succeeded in producing iron in a blast-furnace by first reducing the coal to coke. Darby's blast-furnace in its fundamental principles was identical with the modern furnace. The blast was created by the use of bellows driven by a water wheel, and the use of the more porous coke made possible a more powerful blast and the air could be forced to the centre of the stack. This discovery was an historic event and, as Rickard's well-known aphorism reads, " *the marriage of coal and iron at which Abram Darby officiated as High Priest gave birth to the industrial revolution*". This is no exaggeration.

The scale of the industry at this time may be judged from the fact that the total production of iron in Britain in the year 1740 was only 17,350 tons—the second highest production in the world, Sweden being the highest producer thanks to the large resources of timber surrounding her magnificent ore fields and to the genius and character of her people. The use of coke for the production of iron spread to the iron and coal centres of the country, and by the end of the century was fairly general. The iron industry was transferred from the wooded districts to the Black Country, Yorkshire, the coal districts of Wales, the Forest of Dean, the North East Coast, and to Scotland.

The full benefit of Darby's method could not be obtained by the inefficient water-driven bellows then available. Watt developed his improved steam engine in 1769. This development was much facilitated by Darby's invention, which provided cast iron at a reasonable price and in substantial quantity. Wilkinson's inventions of the cupola, and accurate cylinder boring, made iron castings available to the engine and machinery builders. Conversely, the engines provided by Watt rendered possible the application of increased power for blowing and mechanical power for forging. The application of power to what had previously been handicrafts, particularly in the textile industry, was the beginning of the Industrial Revolution.

Thus was laid the foundation of the factory system. The industrial system as we know it today was born, with its incalculable influence on the creation of a new social order.

Hitherto, these products had been made by individual workers in their own homes, and the producer exchanged the result of his skill and work with others to meet the daily needs of himself and his family.

INDUSTRIAL DEVELOPMENT

In the middle of the eighteenth century it was difficult to find financial resources sufficient to take advantage of the flood of invention which followed the creation of mechanical power. The accumulation of capital for the development of individual skills had been the result of individual effort and remained under the control of the individual; but new demands far transcended the resources of individuals. Fortunately, in 1609 the Bank of Amsterdam had been founded, and the mechanism of commerce and finance began to assume modern shape. The example of the Dutch was followed in England, and in face of strong opposition the Bank of England was founded in 1694. Thus the investment of the savings in industry of those not directly engaged in it became possible.

Another condition which aided this development was that the governing classes of England became interested in industry and commerce. The Whig Lords, requiring money for the maintenance of their power and to discharge what they considered their responsibilities, were not the men to despise fortunes obtainable through factory or mine, particularly as in many cases they owned the land under which the mines were situated. The powerful Nonconformist section of the nation, which was excluded from active

participation in politics until 1828, applied itself with puritanic fervour and energy to the pursuit of opulence. H. A. L. Fisher has written describing their attitude: "*Labour was regarded as a sacrament, pleasure as a sin, the making of wealth as a sign that their service was acceptable to the Lord.*"

One of the characteristics of the Industrial Revolution was the rapidity with which inventions that proved complementary in the development of the industrial system followed one another so closely. While Abram Darby was perfecting the smelting of iron with stone coal, Huntsman of Sheffield in 1740 perfected the production of steel of uniform quality by melting blister steel in clay crucibles placed in coke furnaces. The fundamental character of his invention was the production of crucibles that would withstand the high temperature required.

A century later, Heath and Mushet introduced the use of alloying elements in the form of manganese and tungsten to toughen the steel. Cort invented the grooved rolling mill in 1783 and the process of puddling iron in 1784. In 1828 James Beaumont Neilson heated the blast to the iron furnaces and thus decreased the consumption of coke from 8 to 5 tons per ton of iron produced. However, until Bessemer perfected his pneumatic process barely 100 years ago steel was produced only in small quantities. A year after Bessemer made known his invention, Siemens invented the open-hearth process in England. In 1879, Thomas and Gilchrist introduced the basic lining for steel furnaces and made possible the basic Bessemer process which created the steel industry on the continent of Europe, particularly in the valleys of the Saar and the basin of Briey, where lay abundant deposits of iron ore previously unusable because of its high phosphorus content.

The iron and steel discoveries and inventions of Darby, Huntsman, Cort, Heath, Mushet, Neilsen, Bessemer, Siemens, Thomas, and Gilchrist were paralleled by a brilliant galaxy of inventors connected with the manufacturing industries, resulting from the application of power to handicrafts, only made possible by the production of iron and steel in quantity.

Thus on the basis of the two natural resources which Britain possesses in quantity—coal and iron—did she gain the industrial leadership of the world for a century. America, with her abundant forests, continued to use charcoal for the production of iron for a further 90 years after England had discarded it. The Americans of those days were not a manufacturing people; they produced only sufficient iron for the blacksmith for local uses. It is remarkable that the natural inventiveness of the British should have enabled a nation of only 9 million people (as was the population of Britain in 1800) to secure this flying start and industrial pre-eminence, whilst others with many times its population, and endowed with coal and iron ore to an even greater extent, developed their resources so much later as a result of British experience and instruction. These developments within a century completely changed the conditions of life for millions of mankind throughout the world.

Since those days—as our Past President, Mr. Mitchell, told us in his stimulating Address last year—there has been no revolutionary change in the fundamental cycle of operations by which iron ore is converted into steel. Furnaces have naturally greatly increased in size and output and the electric-arc furnace plays a new and important part. Mechanical appliances and rolling mills have also greatly developed in power and efficiency.

COMMUNICATIONS

Until the advent of the railway in 1825, communication was entirely dependent upon animal transport, which was expensive and relatively scarce. The 120-mile journey from London to Birmingham by coach took 12 hours. As a consequence, production of food, clothing, and the necessities of life generally were limited to the needs of the locality in which the producers lived. The ordinary people who left their birthplace beyond walking distance frequently left for ever. The opening of the Stockton and Darlington Railway in 1825 was the birth of a social and economic revolution which, by the removal of the limitation imposed by distance, permitted the assembly of people and materials promptly and economically wherever they were required. Production was simplified and markets extended so that costs were reduced, employment increased, and the standard of life raised ultimately for the nation as a whole.

George Stephenson improved the locomotive and made it practicable for continuous service. The rails for the Stockton and Darlington railway, 26 miles long, and used for mineral traffic, were made of wrought iron and weighed 28 lb./yd.

In 1829, the Manchester to Liverpool Railway was built for passenger traffic, and the Company offered a prize of £500 for the locomotive that met the conditions they prescribed. Stephenson won the prize with his *Rocket*. Up to 1825 the fastest speed achieved by man was 30 m.p.h. for a few minutes on a race-horse. Stephenson, for a few miles, attained 60 m.p.h. Greville wrote in his famous diary, under the date January 28th, 1834: "*Stephenson, the great engineer, told Lichfield that he had travelled on the Manchester and Liverpool railroad for many miles at the rate of a mile a minute; that his doubt was not how fast his engines could be made to go, but at what pace it would be proper to stop; that he could make them travel with greater speed than any bird can cleave the air, and that he had ascertained that* 400 *miles an hour was the extreme velocity which the human frame could endure, at which it could move and exist.*" Stephenson's figure of 400 m.p.h. does in fact approximate to the maximum velocity since obtained for short distances by motor car, and his prophecy was certainly a bold one to have made 120 years ago. The great Duke of Wellington, on the other hand, remarked after a railway journey: "*I see no reason why these machines should ever come into general use.*"

The early railways were of necessity based on wrought iron as the only suitable material available, until 1856 when the first Bessemer steel rail was rolled at Dowlais Works.

Bryant says: "*By* 1849 *the railway system of England had taken on the general form we know today. All this involved a revolution in English life and organisation. In* 1840 *England was still Regional in its outlook; by* 1850 *it was National due to the influence*

of improved communications by the railways. The opportunity of travel was brought within the reach of all classes by Gladstone's Act of 1845 *requiring the Railway Companies to run at least one train per day with covered third class accommodation on all routes at one penny per mile. This fare eventually became the largest revenue producer to the Railways.*"

In 1850 the total railway mileage in the world was 18,000. By 1860 this had increased to 63,000; in 1870 to 127,000; and in 1878 to 206,000, of which the United Kingdom possessed 17,000 miles. Today the figure for the whole world is 800,000 miles, of which Britain possesses 51,000 with 3000 more of single track in Ireland.

Until steel rails became available, the output of wrought iron rails in Britain was 750,000 tons per annum. Ramsbottom, the civil engineer of the L. & N.W. Railway said that wrought-iron rails lasted only four months in service. After laying one rail of the main-line track at Chalk Farm with steel, and the other with wrought iron, he found that the wrought-iron rail had to be changed 23 times to once for steel. Steel thus became the material for railway tracks. The expansion of railways throughout the world was so rapid that until 1881 more than half the steel production of the world was used for railway track.

Fortunately for the producers of wrought iron, the ship-builders were replacing timber with iron, first in composite ships of wood and iron and then with vessels wholly of iron; this for a time made good the loss of the railway market.

In 1811, the first British steamboat was launched on the Clyde, and during the next thirty years 600 were built. In 1838, the first iron sailing ship crossed the Atlantic. In June 1842, the Great Western steamship reached Bristol from New York in 12½ days, a voyage that had previously taken a month. The world of which industrial Britain was the centre was daily growing smaller.

In 1866, a ship classed at Lloyd's was built of steel produced by the Barrow Haematite Co., with scantlings 25% less than those required for iron. It was not until 1877, however, that steel was used for general shipbuilding, for confidence in the consistent quality of steel had to be established. The advent of steel and the development of steam power gave a tremendous impetus to shipbuilding. In 1848 British-owned tonnage of wood and composite ships was 5,278,000 tons; 100 years later, in 1947, it was 21,549,000 tons, in spite of war loss, and today it is 22,300,000 tons. Neither railways nor shipping would be possible on the present scale without steel.

The present century is notable for the great advance in alloys, both ferrous and non-ferrous. Although ferrous alloys have been known and used for more than a hundred years it is only during the present century, and in the past 30 years in particular, that the scientific principles governing the relation between constitution and physical properties have begun to be understood. Previously, their constitution depended on trial and error to obtain the physical properties required.

The stainless group of alloy steels, discovered by Brearley in 1913, apart from their use for cutlery, ornament, and structures, have made an invaluable though indeterminable contribution to the rising standard of life; indeterminable because they have made possible many manufacturing processes the products of which contribute much to the production and preservation of food, medicine, and personal comfort.

The advance in the production of alloys has had a profound influence on the development and application of mechanical power. The motor car, with its marked impact on social life and distribution of population, would be impossible in its present form, and at its present cost, without the alloys, both ferrous and non-ferrous, made available by scientific and technological progress in recent years. The jet engine was quite impossible of realization in practice until alloy steels, capable of sustaining the stress required at very high temperatures, became available. The power available for aircraft propulsion with the jet engine is 7–8 times per lb. weight greater than that of the piston engine. The full social and economic effect of high-speed aircraft is not yet determinable, but the reduction in time of travel from weeks to hours over long distances must be profound, reminding us of what Ruskin described in 1870 as "*one kingdom of the habitable globe.*"

STRUCTURES

While bridge building has been much facilitated and stimulated by the development of iron and steel in suitable forms, bridges have not had the same dominant social influence as mechanical power, railways, and shipping. They have made communities, sources of materials, and foodstuffs more accessible, but without them alternative means of communication—although often much longer and more costly—are in most cases available.

The first iron bridge, built across the Severn in 1787 at Ironbridge, still stands. The suspension bridge by Telford in 1826, and the tubular railway bridge by Stephenson (1849–50), over the Menai Straits, are of wrought iron and still in service, as also is the Newcastle high-level bridge of cast iron built by Stephenson (1846–50), carrying both rail and roadway.

The first steel bridge was the Forth Bridge (1890), designed by Sir John Baker and built by Sir William Arrol, and the forerunner of many notable bridges throughout the world. The most famous is the Sydney Bridge with a span of 1650 ft. across Sydney Harbour.

RESEARCH

During the last half of the nineteenth century, and particularly in the last quarter, the speed of invention in manufacturing processes received a remarkable impetus as a result of the discovery of the fundamental scientific principles on which industrial processes depend. Most of these had been devised empirically by trial and error.

Science is generally defined as systematized knowledge, but it is broadly true to say that it was not until the present century that organized collaboration was established between science and industry. The scientist and the technologist had few points of contact and little understanding of the potentialities and limitations of each other, which only collaboration between the two could develop

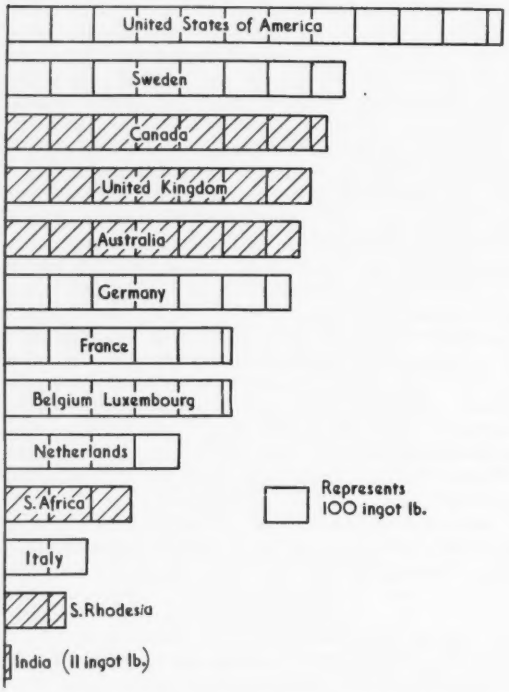


Fig. 1—Apparent consumption of steel per head of population in 1952

and remove. The introduction of scientists to the industrial field, and a scientific appreciation of the technologist, resulted from the development of the application of the scientific method to industrial processes, which has extended to the study of materials, their properties and constitution—and even to their synthesis and manipulation. The scientific method has also been applied to the deployment of plant and personnel, which, together with the study of the problems of administration, have produced a new technology of management. It must be admitted that for many years industry resolutely kept scientists in a separate department from those concerned with production—for consultation only as and when required. As a consequence neither side could understand or appreciate the wide field for co-operation which existed, the exploitation of which has produced a second industrial revolution in the last 30 years. The war of 1914 gave a stimulus to the collaboration of the scientist and the producer, by its demand for the immediate supply of new arms, machinery, materials and devices, irrespective of cost. Thus the application of scientific knowledge to industrial production was probably at least ten times faster during the war period than would have been possible without the spur of necessity provided by a struggle for survival.

Research has now become recognized as an essential part of the equipment of industry: the steel industry was one of the first to establish research laboratories in the larger works. In 1924 the British

Table I

APPARENT CONSUMPTION OF STEEL PER HEAD OF POPULATION

	U.S.A.	Canada	Sweden	Australia[1]	U.K.[2]	Germany[3]	Belgium/ Luxembourg	Nether- lands	France[4]	Italy	South Africa	Southern Rhodesia	India
Population, thousands													
Average 1937–1938	129,465	11,394	6,287	6,873	47,392	68,195	8,660	8,641	41,185	42,534	9,897	1,383	372,631[5]
1948	146,621	13,167	6,883	7,645	50,065	46,402	8,849	9,800	42,116	45,706	11,890	1,943	342,120
1952	156,981	14,430	7,126	8,540	50,429	48,478	9,007	10,377	43,565	46,865	12,912	2,233	367,000
Apparent Ingot Consumption, thousand long tons													
Average 1937–1938	36,964	1,709	1,352	1,313	10,430	18,278	1,362	1,284	5,309	2,328	864	57	1,229[5]
1948	74,126	3,570	1,908	1,439	13,827	5,275	2,254	1,550	7,683	2,264	1,129	54	1,387
1952	79,521	4,762	2,473	2,588	15,897	14,305	2,100	1,846	10,173	3,930	1,673	139	1,813
Ingot Consumption per Head, ingot lb.													
Average 1937–1938	640	336	532	428	493	600	353	333	289	123	195	93	7[6]
1948	1,132	607	621	422	619	255	571	354	409	111	213	62	9
1952	1,135	739	778	679	706[6]	661	522	399	523	188	290	140	11

[1] Year ended 30th June
[2] Adjusted for stock changes
[3] Includes the Saar in 1937 and 1938; West Germany only 1948–1952
[4] Includes the Saar 1948–1952
[5] 53 weeks
[6] Including Pakistan

Iron and Steel Federation set up a co-operative Research Committee with which the Department of Scientific and Industrial Research and this Institute were associated. This has now developed into the largest co-operative industrial research organization in Britain, still in collaboration with the D.S.I.R. and The Iron and Steel Institute.

Within the compass of a short address it is only possible to indicate the relation between the development of the production of steel and the advance of material civilization. Since it is evident that such advance could not have been made in the same time without the discovery and production of steel, it is a logical deduction that this, in the centuries to come, will be called the Steel Age to distinguish it from those which preceded it.

GROWTH OF POPULATION

The increase in population of the United Kingdom from 1740 to the present time could not have been supported without the development of transport and productive machinery, and the application of mechanical power to manufacturing industry and agriculture, which steel alone made possible. The population of England and Wales in 1066 has been computed at between 1½ and 2 millions; the iron production was then insignificant—possibly a few hundred tons. It rose to about 50,000 tons in the year 1760 and then increased rapidly (as a result of the application of stone coal to iron smelting, and the Industrial Revolution) to 4,000,000 tons in the year 1860. The first national figures available for steel production in the United Kingdom were 160,000 tons in 1869—iron production in the same year being 5,450,000 tons. Steel production for the present year has been in recent months at the rate of 18½ million tons per annum. The rate of growth of population and production of pig iron and steel from 1740 to 1953 is shown in Fig. 1.

It is, of course, correct to say that the increase in population is not directly related to the production of steel, but rather to the advance of human knowledge in all factors concerning our material civilization, including medicine, health, and hygiene generally. If reduced to its simplest elements, this advance in human knowledge would not have been possible without the increase in productivity and the creation of wealth brought about by the conversion of the natural resources of the earth to the service of man. This in turn has depended upon the application of steel to the creation of prime movers and of power to manufacturing machinery, tools, etc., all based on the production of steel of varying qualities to suit the services required. Thus it is obvious that the rate of consumption of steel per head of population is some measure of the rate of material development

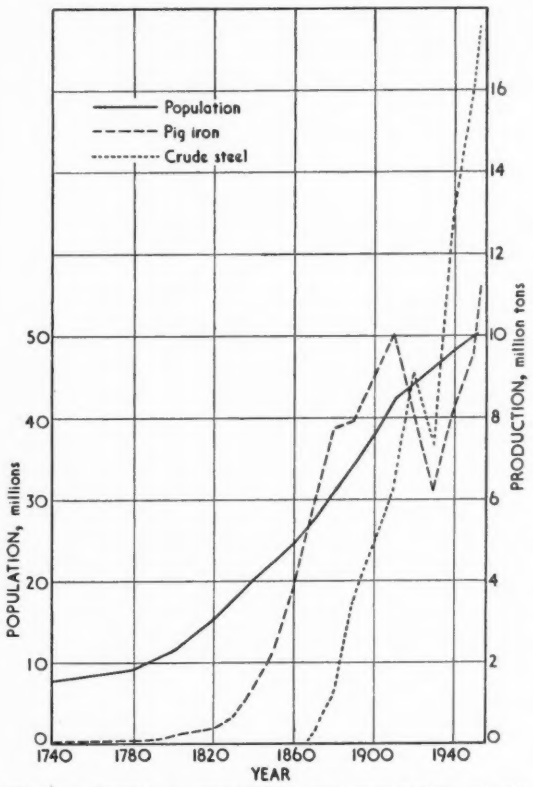


Fig. 2—Growth of population, and production of pig iron and crude steel in the United Kingdom

Table II

DELIVERIES OF FINISHED STEEL TO INDUSTRIES IN 1951

Provisional figures including sheet and tinplate

Industry	Thousand tons	Percentage of Total
Coal mining	566	5·3
Other mining and quarrying	10	0·1
Iron and steel	371	3·4
Shipbuilding and repair	727	6·7
Marine engineering	127	1·2
Agricultural machinery	166	1·5
Boilers and boiler-house plant	153	1·4
Machine tools	68	0·6
Stationary engines	29	0·3
Textile machinery and apparatus	65	0·6
Constructional engineering	902	8·4
Other non-electrical engineering	948	8·8
Electrical machinery and apparatus	437	4·1
Motors, cycles, aircraft	1089	10·1
Rolling stock—Railway Executive	198	1·8
Rolling stock—other makers	327	3·0
Bolts, nuts, screws, etc.	439	4·1
Drop forgings, laminated springs, etc.	434	4·0
Wire manufactures	290	2·7
Hollow-ware	627	5·8
Metal furniture, windows, etc.	484	4·5
Tools, implements, etc.	108	1·0
Building and contracting	407	3·8
Gas, electricity, water	94	0·9
Railways (excluding rolling stock)	291	2·7
Other U.K. consumers	338	3·1
Stockholding merchants	1094	10·1
Totals	10,789	100·0

[1] Year ended 30th June
[2] Adjusted for stock changes
[3] Includes the Saar in 1937 and 1938; West Germany only 1948–1952
[4] Includes the Saar 1948–1952
[5] 53 weeks
[6] Including Pakistan

of a country. Figure 2 indicates this for 13 countries and shows that the consumption of steel per head was greater in Sweden and Canada during 1952 than in the United Kingdom, and that in Australia it is nearly equal. The apparent consumption of steel per head of population in recent years is compared with that in the pre-war period in Table I.

THE FUTURE

What of the future? The Steel Age as we know it is barely 100 years old. Its birth can hardly be dated earlier than Bessemer's invention in 1856, although steel as a separate product was known and made for many centuries before this. It was produced commercially by Huntsman in 1740 by his cementation process. But its cost at that time was of the order of £60 per ton, and it was Bessemer's ambition—which he ultimately achieved after years of experiment—to reduce this to £12 per ton. It may be said that whilst the previous inventions made a valuable contribution to technological advance in the production of tools and the like, it was not until steel was generally available for structural use and the mechanism of daily life that it exerted the profound influence on the social life and wellbeing of mankind that is so characteristic of the present century. Table II illustrates the dependence of our industrial economy on steel, thus making it the foundation of our present social standing and material prosperity.

How long will it last? And what is likely, if anything, to supersede it? These are intriguing and pertinent questions, to which, in our present state of knowledge, no definite answer can be given. The important advances that have already been made in the development of steel to meet extreme limits of stress at high temperatures, the reduction of corrosion under service conditions, the great advance in the understanding of metallurgical phenomena governing the physical and chemical qualities of the alloys of iron and other elements, have extended the potentialities of the Steel Age to a point that transcends our imagination. An important factor in its use in structures is obviously that of weight/service ratio attainable in relation to cost. Light alloys with an aluminium base have already proved their physical capacity to give a very high weight/service ratio, but at a cost which at present places them out of competition with steel. There is every probability that the weight/service ratio of iron alloys can be substantially increased by the use of plastic methods of design and the introduction of new alloys.

Those who are engaged in research will no doubt continue to pursue their unending quest with that enthusiasm by which the achievement of an objective only opens up new horizons to be explored.

The influence of the industry on the development of our material civilization is thus paramount. It will no doubt increase over an ever-wider area of the world more and more rapidly as our own efforts in promoting the collaboration of all concerned, which has been such a marked feature of the last 30 years, become more and more effective in bringing—through institutions such as this—the knowledge and experience of each to the notice of all. The most important function of this Institute and similar societies is to unite all those engaged in it, throughout the world, in the common purpose of promoting its progress, not only for the economic rewards alone, but also for the furtherance of the Arts of Peace for the benefit of mankind. Thus our great industry should exert a major influence in bringing permanent peace to a discordant world.

I wish gratefully to acknowledge the generous help I have received from many friends, including the officials of this Institute and of the British Iron and Steel Federation, without which this address could not have been written.

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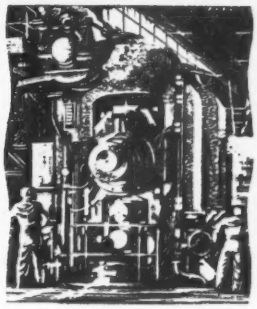

The Strain Ageing of Mild Steel

A CRITICAL INVESTIGATION OF THE AGEING OF MILD-STEEL STRIP AFTER TEMPER-ROLLING

By B. Jones, D.Sc., and R. A. Owen-Barnett, B.Sc.

SYNOPSIS

The ageing characteristics of rimming and killed steels of basic O.H. and basic Bessemer origin have been investigated after temper-rolling. Ageing of the steels at room temperature for periods up to 3 years has been compared with artificial ageing at temperatures of 100–250° C. It is shown that the latter treatment gives high values of yield stress, yield ratio, and yield-point elongation in O.H. rimming steels, but more comparable results in basic Bessemer steels. Greatest differences in physical properties are obtained in killed steels by ageing at these temperatures, for apart from high values of yield stress and yield ratio, a return of the yield point was shown at 200–250° C. After noting the advantage found by ageing at 100° C., lower temperatures have been tested, and the results show that the speed of ageing can be followed, and results obtained in all steels are more comparable with the fully aged condition. Results obtained by treatment of the temper-rolled steels for 1 day at 75° C. are to all intents and purposes the same as those found by natural ageing for 1-3 years. The effect of cold storage at 0° and —15° C. has also been investigated for periods of up to 6 months. There was an appreciable retardation in the rate of ageing of rimming steels, which were particularly stabilized after storage at —15° C. The comparative non-ageing properties of aluminium-killed steel were further improved by cold storage. The results obtained on the various steels are discussed. 943

Introduction

ALTHOUGH the effects of ageing of low-carbon steels after various kinds of straining have been known since about 1880, the subject has been of special interest during the last 20 years owing to its significance in the applications of steel sheet and strip in cold pressing and deep-drawing operations. During this period, the production of flat-rolled products has increased enormously through the development of continuous rolling mills, following a demand for steel strip for many new applications.

In the production of steel sheet and strip for cold pressing, it is standard practice to apply a light degree of cold work by temper-rolling after an annealing treatment, so as to strain the steel sufficiently to remove the yield point and prevent the formation of 'stretcher-strain' surface markings during the forming process. These strain bands, caused by localized plastic deformation in annealed and strain-aged steel, are associated with the characteristic elongation at the yield point in an autographic load/elongation or stress/strain curve in a tensile test. After the temper-rolling of rimming steels, the yield point will reappear after a time as a result of ageing; this causes an unsatisfactory condition of the surface during cold forming, with an increase in yield strength and yield ratio, and a loss of ductility. Reference should be made to the excellent papers by Kenyon and Burns,[1–3] who showed clearly the effects of ageing on autographic stress/strain curves of low-carbon steel sheet after temper-rolling. Tests were described for a rapid assessment of ageing by heating the steels to low temperatures after straining. The amount of work on strain-ageing up to 1939 will be appreciated by a consideration of the 382 references given in the A.S.M. Symposium by Kenyon and Burns.[3]

As it is known that low-carbon steels show ageing effects to varying degrees, great interest has been

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Table I

CHEMICAL ANALYSES OF THE STEELS

Steel	C, %	Mn, %	S, %	P, %	Cu, %	Ni, %	Cr, %	Mo, %	N_s, %†	Al, %
Pure iron (*BS*)	·002	·005	·002	·002	·020	·002	·001	...	·001	·003
Basic O.H. rimming (*BQ*)	·05	·33	·027	·014	·06	·07	·02	·01	·005	<·005
Basic O.H. rimming (*BF*)	·05	·35	·045	·013	·10	·05	·01	<·01	·006	<·005
Improved basic Bessemer rimming (*AL*)	·04	·40	·021	·017	·03	·04	·01	<·01	·010	·005
Basic Bessemer rimming (*AK*)	·05	·32	·055	·045	·05	·05	·01	<·01	·015	·005
Basic O.H. V-treated rimming (*BX*)*	·07	·32	·029	·015	·11	·08	·04	<·01	·005	·005
Basic O.H. Al-killed (*BL*)	·08	·34	·038	·026	·08	·04	·01	<·01	·004	·080
Ugiperval (*BN*)	·05	·32	·015	·014	·02	·03	·02	<·01	·013	·075

* Vanadium, 0·028% † Insoluble N_s of the order of 0·0005% except *BX*, 0·005% and *BN*, 0·011%

shown in tests for the assessment of the ageing characteristics by more rapid methods than by waiting for results over a long period. Differences are found in the ageing of steel strip rolled from similar casts of O.H. steel and even of parts of the same ingot, and in the ageing of steels of different manufacture. Bessemer steels age more rapidly than O.H. steels, because of a higher nitrogen content ; in recent years an improved Bessemer steel has been developed with a lower nitrogen content and with strain-ageing properties more comparable with O.H. steels. Non-ageing steels have been developed since 1933 to overcome these difficulties in mild steel by treatment with aluminium and titanium (fine-grained and stabilized steels),[2] and the tonnage of this class of steel for cold forming is gradually increasing in the U.K., although the total amount passing through the press shops is still limited because of its increased cost. Epstein, Cutler, and Frame[10] have developed a non-ageing rimming steel containing a small addition of vanadium, but for general purposes the higher cost of this steel is also a factor in its application. As the ordinary-quality rimming steel is used extensively for cold forming, methods of avoiding strain-ageing for a longer time during storage would be desirable. The trouble is not confined to flat-rolled products, as the comparative embrittlement of mild steel after cold work and storage is also found in such products as wire and cold-drawn bars. After prolonged storage, *e.g.*, during shipment for export, particularly if the steel is exposed to a warm environment, the physical properties can be seriously affected. The control of storage temperature is important, and little work on this subject in regard to mild steel has been published. Coker[12] investigated the effect of lowering the temperature on the recovery of steel from overstrain, and Püngel, Lieberknecht, and Schulz[14] reported the change of properties of steel wire on storage at 0° and −20° C. The effect of retarding the age-hardening of Duralumin[13] by cold storage after solution treatment is well known.

TESTS FOR THE AGEING OF STEEL SHEET AND STRIP

Published work on ageing tests refers to the following treatments :

(i) Temper-rolling, or ' skin-passing ',[1, 4–6] followed by normal ageing at room temperature, or accelerated ageing at 100–250° C.

(ii) Tensile straining to extensions between 6% and 10% elongation of the gauge length, followed by accelerated ageing at 100–250° C., the percentage increase in yield stress giving an ' ageing index ' of the steel[7–11]

(iii) Hot tensile testing at 205° C., a method devised by Kenyon and Burns.[2] A steel susceptible to strain-ageing was shown to have an increased strength at this temperature, as compared with that at room temperature, whereas a stabilized or non-ageing steel has a reduced tensile strength under the same condition. It was stated that strain-ageing and blue-brittleness are different manifestations of the same phenomenon. Hot tensile tests at 205° C. only provided an indication of whether a steel was ageing or non-ageing in character after cold work.

Tests on mild steel after tensile straining do not give results that can be compared with those obtained by a light temper-rolling, because the minimum percentage reduction in area required to remove the yield point is appreciably greater with tensile straining than with temper-rolling. For example, most annealed steels require a minimum of 6% elongation by tensile straining to remove the yield point, whereas this is effected by 1–2% cold reduction by temper-rolling. Ageing tests made on various mild steels after tensile straining to 6% and 10% elongation of the gauge length showed that the rate of ageing at room temperature was much greater than after temper-rolling, a return of the yield point being observed in all steels in less than one day after tensile straining.

The authors have therefore not included tests by tensile straining, as the results obtained are not an accurate indication of the ageing characteristics of mild steel at room temperature after light temper-rolling.

EXPERIMENTAL DETAILS

Scope of the Investigation

For some years the authors have carried out tests on the ageing of steel strip of various qualities after temper-rolling. Some of the results obtained are given in this paper, which deals with the ageing of various low-carbon steels after sub-critical annealing and temper-rolling. After rolling, the steels were tested at room temperature at intervals of time up to 3 years, and after accelerated or artificial ageing at 100° C. for 1 day, 200° C. for 3 hr., and 250° C. for 1 hr., as advocated in the published literature. In view of the results obtained at these temperatures, tests were carried out at 50° and 75° C. for various

times after temper-rolling, as it was considered that treatment at temperatures lower than 100° C. would give results nearer to those obtained in steels fully aged at room temperature. As the rate of ageing of mild steel after temper-rolling depends markedly upon the temperature to which it is subsequently exposed, it was evident that the rate of strain-ageing would be retarded at low temperatures. The effect of storage of temper-rolled mild-steel strip at 0° and −15° C. was investigated. The results obtained at these temperatures are compared with those obtained by ageing at room temperature.

Treatment of the Steels

The chemical analyses of the steels are shown in Table I. They included two basic O.H. steels, two basic Bessemer steels of different nitrogen content, an aluminium-killed basic O.H. steel, and Ugiperval steel of basic Bessemer origin. A vanadium-treated rimming steel and a pure iron were aged at 100–250° C. only, as insufficient samples were available at the time for other ageing tests.

The general procedure was to hot-roll coils of strip from slabs or billets in a continuous rolling mill ; these were pickled and cold-reduced 60% in thickness in a tandem mill. A coil 1 in. wide was obtained by slitting the hard-rolled strip at the centre ; from this coil, 6-in. lengths were sectioned, those of constant gauge being used in the tests. These pieces were bright-annealed in an atmosphere of partially burnt town gas in an electric annealing plant at 700° C., and were temper-rolled for the ageing tests. Steels *BX* and *BN*, however, were received as annealed sheets. Pure iron *BS*, received as thick strip, was annealed at 950° C. and cold-reduced 60% in thickness ; tensile pieces were then machined, and annealed at 930° C. to impart a uniform grain size. Annealing of the pure iron was carried out *in vacuo* to avoid surface contamination. For ageing tests, pieces of all steels were machined to standard tensile test pieces (B.S. Specification No. 18 Test Piece *A*, 2-in. gauge length) before annealing and rolling. The steels were temper-rolled $1\frac{1}{2}$–$3\frac{1}{2}$% in a single-stand 4-high Davy United mill with $8\frac{3}{4}$-in. dia. work rolls at a slow speed of about 200 ft./min., the required reduction being mostly obtained in one pass. This degree of temper removed the yield point under the conditions stated and caused some strain-hardening. The cold reduction required to remove the yield point depends on various factors, such as the size and condition of the work rolls, the lubricant or coolant, the type of steel, its analysis and grain size, the speed of rolling, and tension. Autographic stress/strain curves of the steels were obtained with a Hounsfield tensometer, fitted with a motorized drive and geared to give a constant straining rate of 0·05 in./in./min. Tensile and Vickers diamond hardness tests were carried out immediately after temper-rolling, and after intervals of time up to 3 years during storage at room temperature, which was maintained at 20 ± 2° C. by storage in an insulated box desiccator. Similar tests were carried out on O.H. steel *BQ*, Bessemer steel *AK*, and aluminium-killed steel *AL* after cold storage. For this purpose, a series of tensile and hardness test pieces were temper-rolled 3% ; part of this series was stored at 20° C. and

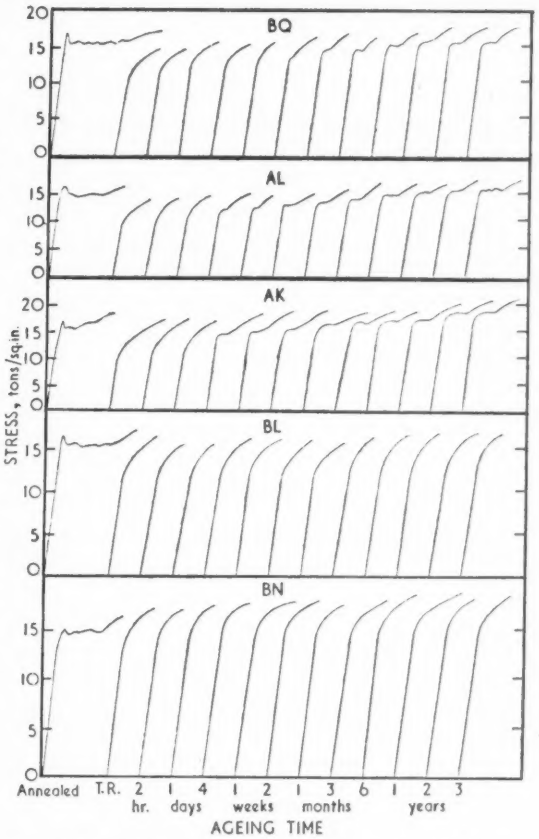

Fig. 1—Characteristics at yield stress of steels annealed, temper-rolled, and aged up to 3 years

the remainder in a specially constructed refrigerator with compartments controlled at temperatures of 0° and −15° C. The steels were withdrawn from cold storage and tested at intervals of up to 6 months, and the steels stored at room temperature were tested after the same intervals. Artificial ageing tests were carried out at 100–250° C., and for various times up to 7 days at 50° and 75° C. in thermostatically controlled oil baths.

EXPERIMENTAL RESULTS

Ageing at Room Temperature

The results are given in Table II, and autographic curves, showing the characteristics at the yield stress after ageing at room temperature, are given in Fig. 1. Table II confirms that a light temper-rolling decreases the yield stress, with only an insignificant change in the ultimate stress, a smooth stress/strain curve being obtained. In the freshly temper-rolled steels, the yield stress quoted is the stress at which the load/elongation curve departs from a straight line. This value is not called the limit of proportionality, owing to the lack of sensitivity of the strain-measuring device. Table II shows values of 'yield-point elongation ratio', *i.e.*, the percentage ratio of the yield-point elongation to the total elongation in the autographic curve. This ratio shows more clearly the relation of

Table II

AGEING OF STEELS AFTER TEMPER-ROLLING FOR 1–3 YEARS

Steel	Time of Ageing	Yield Stress, tons/sq. in.	Yield-Point Elongation Ratio, %	Ultimate Stress, tons/sq. in.	Elongation on 2 in., %	Hardness, D.P.N.
Pure iron (*BS*), 2·4% reduction	Annealed	6·8	5·4	15·6	46	61
	15 min.	7·3	0	15·9	46	72
	100° C. (24 hr.)	9·7	3·0	16·0	46	74
	200° C. (3 hr.)	9·7	3·5	16·0	46	74
	250° C. (1 hr.)	9·8	3·0	16·0	43	75
O.H. rimming (*BQ*), 2·7% reduction	Annealed	15·6	14·0	20·0	42	89
	15 min.	11·5	0	20·1	41	98
	2 hr.	12·0	0	20·0	41	98
	1 day	12·9	0	20·2	39	99
	4 days	13·1	0	20·3	40	100
	1 week	13·6	0	20·3	40	100
	2 weeks	14·1	0·9	20·6	37	102
	1 month	14·9	1·3	21·1	38	105
	3 months	15·1	2·6	21·2	37	107
	6 months	15·6	4·1	21·5	35	108
	1 year	15·9	4·3	21·8	33	107
	2 years	15·8	4·4	21·8	34	107
	3 years	16·0	4·5	21·9	33	108
	100° C. (24 hr.)	17·3	10·5	21·8	34	110
	200° C. (3 hr.)	17·8	13·1	22·0	31	112
	250° C. (1 hr.)	18·0	13·2	22·6	30	112
O.H. rimming (*BF*), 1·5% reduction	Annealed	15·5	13·6	19·8	43	89
	15 min.	10·4	0	20·0	42	93
	2 hr.	10·7	0	20·1	42	93
	1 day	11·0	0	20·1	41	95
	4 days	12·1	0	20·2	41	97
	1 week	12·4	1·1	20·2	41	98
	2 weeks	13·1	3·0	20·4	41	99
	1 month	13·4	5·7	20·4	39	100
	3 months	13·8	4·4	20·9	37	101
	6 months	14·8	4·5	21·1	35	102
	1 year	15·2	4·7	21·2	34	103
	2 years	15·3	4·4	21·4	34	104
	3 years	15·1	4·8	21·2	34	104
	100° C. (24 hr.)	16·0	9·8	20·6	35	105
	200° C. (3 hr.)	16·4	10·8	21·3	33	106
	250° C. (1 hr.)	16·9	13·4	22·0	32	107
Basic Bessemer rimming (*AL*), 1·5% reduction	Annealed	14·5	12·4	20·7	39	92
	15 min.	10·0	0	21·1	38	99
	2 hr.	10·3	0	21·2	39	100
	1 day	11·0	0	21·2	38	101
	4 days	12·2	0·9	21·3	36	101
	1 week	12·6	1·9	21·3	35	102
	2 weeks	13·1	3·2	21·4	35	101
	1 month	13·5	4·7	21·5	33	103
	3 months	14·0	3·0	21·8	32	105
	6 months	14·8	2·7	22·2	30	106
	1 year	15·3	5·0	22·8	28	107
	2 years	15·6	4·1	22·9	28	110
	3 years	16·0	5·2	22·5	29	109
	100° C. (25 hr.)	16·0	10·7	22·5	30	108
	200° C. (3 hr.)	16·2	10·3	22·8	29	110
	250° C. (1 hr.)	16·6	10·0	22·7	29	111

Table II—(*contd.*)

AND AFTER ARTIFICIAL AGEING AT 100–250° C.

Steel	Time of Ageing	Yield Stress, tons/sq. in.	Yield-Point Elongation Ratio, %	Ultimate Stress, tons/sq. in.	Elongation, on 2 in., %	Hardness, D.P.N.
Basic Bessemer rimming (*AK*), 1·6% reduction	Annealed	15·9	15·0	22·6	36	106
	15 min.	10·4	0	23·0	34	110
	2 hr.	11·0	0	23·0	33	111
	1 day	11·6	0	23·1	33	115
	4 days	14·7	1·9	23·2	32	119
	1 week	15·1	2·4	23·2	31	120
	2 weeks	15·8	5·3	23·5	28	120
	1 month	16·6	5·3	23·5	27	121
	3 months	17·5	6·6	23·8	26	122
	6 months	18·1	6·5	24·0	25	125
	1 year	18·6	6·8	24·5	26	126
	2 years	19·1	7·1	24·7	25	123
	3 years	19·4	6·9	24·6	24	122
	100° C. (24 hr.)	19·3	7·5	24·6	25	125
	200° C. (3 hr.)	19·5	9·6	24·8	22	127
	250° C. (1 hr.)	19·7	11·5	25·1	21	129
V-treated rimming (*BX*), 3·4% reduction	Annealed	18·9	15·0	21·2	43	105
	15 min.	14·2	0	21·5	42	112
	100° C. (24 hr.)	15·1	0	21·8	40	114
	200° C. (3 hr.)	16·1	0	22·1	39	116
	250° C. (1 hr.)	16·3	0	22·5	37	118
O.H. Al-Killed (*BL*), 2·9% reduction	Annealed	15·7	14·4	20·5	40	100
	15 min.	12·2	0	21·3	40	106
	2 hr.	12·3	0	21·8	40	106
	1 day	12·5	0	21·6	40	106
	4 days	12·8	0	21·3	41	107
	1 week	13·0	0	21·4	40	107
	2 weeks	13·1	0	21·6	40	108
	1 month	12·9	0	21·7	40	109
	3 months	13·1	0	21·7	39	109
	6 months	13·4	0	21·7	39	109
	1 year	13·5	0	21·7	39	110
	2 years	13·9	0	21·6	39	110
	3 years	13·9	0	21·8	40	110
	100° C. (24 hr.)	15·0	0	21·7	39	110
	200° C. (3 hr.)	15·9	2·5	21·9	39	110
	250° C. (1 hr.)	16·4	3·7	22·0	38	112
Ugiperval (*BN*), 3·3% reduction	Annealed	14·5	10·0	19·7	44	90
	15 min.	13·2	0	20·3	39	99
	2 hr.	13·5	0	20·3	39	100
	1 day	14·0	0	20·3	38	99
	4 days	14·6	0	20·3	38	101
	1 week	14·8	0	20·4	37	101
	2 weeks	14·9	0	20·5	37	100
	1 month	14·6	0	20·5	37	103
	3 months	14·8	0	20·7	37	104
	6 months	15·3	0	21·0	36	106
	1 year	15·5	0	21·0	36	108
	2 years	15·9	0	21·0	35	107
	3 years	15·8	0	21·0	35	108
	100° C. (24 hr.)	16·1	0	20·9	34	108
	200° C. (3 hr.)	17·1	3·8	21·1	33	110
	250° C. (1 hr.)	18·4	3·3	21·7	31	112

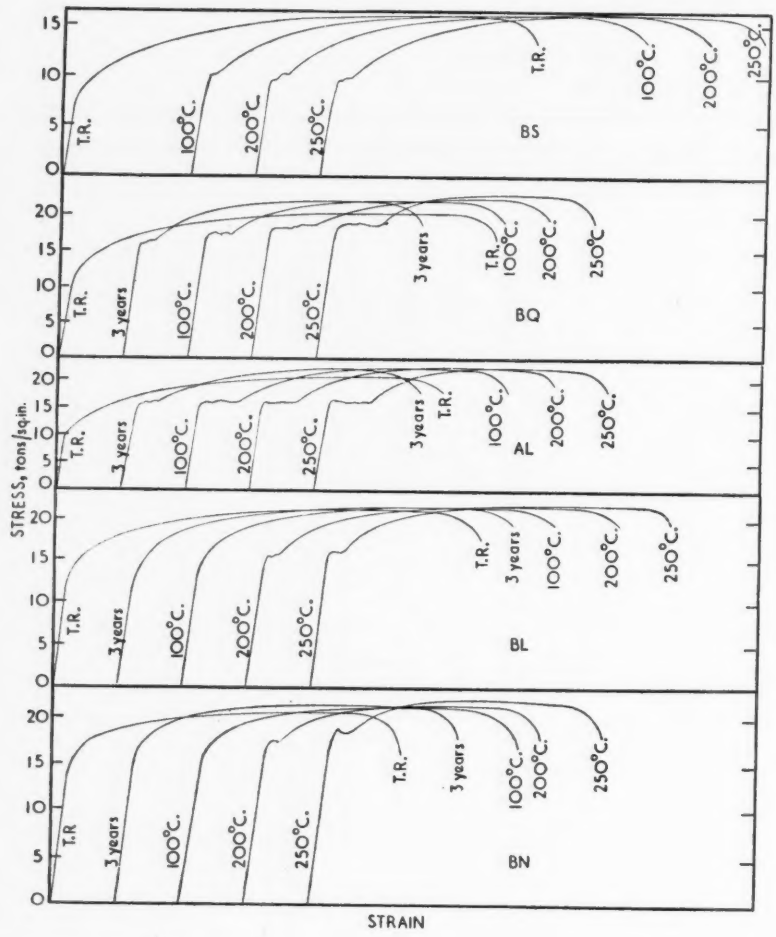

Fig. 2—Stress/strain curves of steels temper-rolled, aged for 3 years, and artificially aged at 100—250° C.

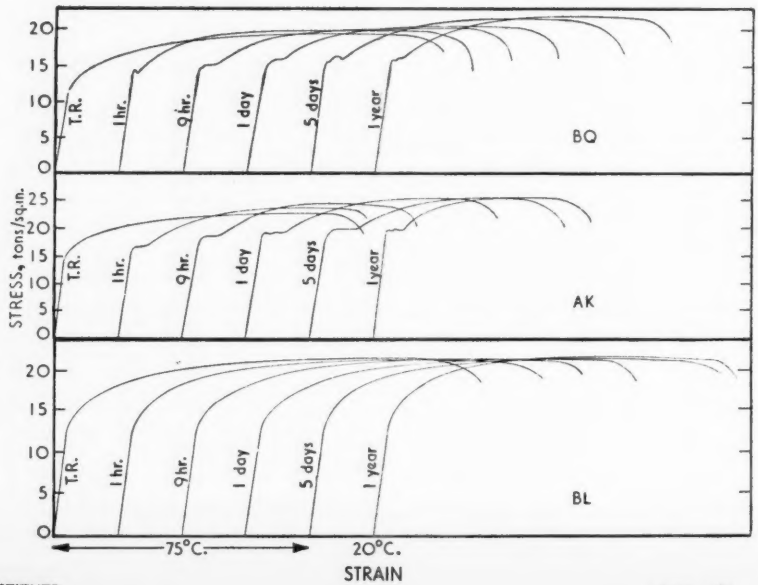

Fig. 3—Steels aged at 75° C. for various times, and a comparison with steels fully aged at room temperature

the yield-point elongation to the decreasing total elongation during ageing.

O.H. and Bessemer Rimming Steels—The effect of ageing O.H. and Bessemer steels after temper-rolling is a return of the yield point, a gradual increase in yield strength, in yield/ultimate-stress ratio and in hardness, and a decrease in percentage elongation. This is a frequent cause of ' buckles ' in pressing operations owing to the reduced ductility, apart from the appearance of strain bands or 'stretcher-strain' markings in the surface. These changes are greatest in basic Bessemer steel such as *AK* with a high nitrogen content, in which the yield stress increases rapidly in one week and continually for 3 years, with an appreciable loss in ductility and an increase in hardness. Similar changes occur in O.H. steel, but to a lesser degree, as shown in steels *BQ* and *BF*, which were temper-rolled by different amounts. The improved Bessemer steel *AL* shows ageing effects intermediate between steel *AK* and the O.H. steels. The yield point returned in the O.H. steels after 1 or 2 weeks according to the degree of temper-rolling, and in basic Bessemer steels in 4 days. After its reappearance, the yield-point elongation is very small, but gradually increases with time ; in the fully aged condition it attains a value less than one-third of that for the annealed steel. The yield stress of the O.H. steels *BQ* and *BF* and improved Bessemer steel *AL* gradually increased on ageing, and, when fully aged, approached the value of the annealed steel. The yield stress of the Bessemer steel *AK* increased rapidly ; it attained the value for the original annealed steel in 2 weeks, after which it progressively increased by a further $3\frac{1}{2}$ tons/sq. in. in the fully-aged condition.

Killed Steels—T e yield point did not return in steels *BL* and *BN* even after 3 years of ageing. The changes in ultimate stress and percentage elongation are negligible in steel *BL*, but there is a small but definite increase in yield stress and hardness. These are lower than those in O.H. rimming steels with a similar degree of temper-rolling. The changes on ageing in Ugiperval steel *BN* as compared with steel *BL* are probably caused by the high nitrogen content (0·013%) due to its Bessemer origin.

Table III

AGEING OF STEELS AT 50° C.

Steel	Time of Ageing	Yield Stress, tons/sq. in.	Yield-Point Elongation Ratio, %	Ultimate Stress, tons/sq. in.	Elongation, on 2 in., %	Hardness, D.P.N.
O.H. rimming (*BQ*), 2·8% reduction	1 year at room temp.	15·9	4·3	21·8	33	107
	As T.R.*	11·5	0	20·4	42	97
	1 hr.	12·2	0	20·5	41	98
	3 hr.	12·8	0·8	20·6	41	99
	6 hr.	13·3	1·3	20·7	40	100
	9 hr.	13·6	1·9	20·7	40	101
	12 hr.	13·8	1·2	20·8	39	102
	1 day	14·2	2·6	20·9	37	104
	3 days	14·8	3·6	21·2	33	107
	5 days	14·9	4·0	21·3	34	107
	7 days	15·0	4·3	21·9	30	108
Basic Bessemer rimming (*AK*), 3·0% reduction	1 year at room temp.	19·8	7·0	25·9	22	135
	As T.R.*	14·1	0	22·9	32	118
	1 hr.	15·2	0	23·1	28	122
	3 hr.	17·0	2·5	24·3	25	126
	6 hr.	17·8	4·9	25·1	23	129
	9 hr.	18·0	5·5	25·3	22	130
	12 hr.	18·2	4·7	25·0	23	130
	1 day	18·5	7·8	25·1	22	133
	3 days	18·6	7·8	25·3	23	132
	5 days	18·4	6·9	25·3	23	133
	7 days	19·0	6·5	25·9	23	133
O.H. Al-killed (*BL*), 3·0%, reduction	1 year at room temp.	13·5	0	21·7	39	111
	As T.R.*	12·4	0	21·2	44	106
	1 hr.	12·5	0	21·5	41	107
	3 hr.	12·8	0	21·3	39	107
	6 hr.	12·8	0	21·3	42	107
	9 hr.	12·9	0	21·0	39	108
	12 hr.	13·0	0	21·3	42	108
	1 day	13·4	0	21·3	39	109
	3 days	13·4	0	21·2	40	110
	5 days	13·5	0	21·4	39	111
	7 days	13·6	0	21·7	39	112

*T.R. = Temper-rolled

Artificial Ageing at 100–250° C.

The accelerated or ' hot-ageing ' tests on the steels are compared with normal ageing tests in Table II. The stress/strain curves of some of the steels and pure iron are given in Fig. 2, which also shows curves for temper-rolled steel before and after ageing for 3 years.

O.H. Rimming Steels—The yield stress and yield-point elongation in steels *BQ* and *BF* are higher after artificial ageing than after ageing for 3 years at room temperature.

Basic Bessemer Rimming Steels—Steels *AL* and *AK* show less marked differences between natural ageing for 1–3 years and artificial ageing, as, apart from the higher yield-point elongation after artificial ageing, the results at the three temperatures agree fairly well with those in the fully aged condition. This is due to the more rapid rate of ageing of Bessemer steel at room temperature. The best results for both O.H. and Bessemer steels are obtained at 100° C., and there is no advantage in higher temperatures.

Killed Steels—The widest divergence from the fully aged condition is found in these steels, and the three temperatures give varying results. The results closest to those in the fully aged condition are again obtained at 100° C. Treatments at 200° and 250° C. show a small yield point at different values of yield stress. The highest yield stress is obtained at 250° C., steel *BN* showing greater differences in physical properties at this temperature. Results obtained by the artificial ageing of aluminium-killed steel cannot be compared with those obtained from natural ageing.

Vanadium-Treated Rimming Steel—Unlike the killed steels, there is no return of the yield point after the artificial ageing treatments, but the yield ratio is increased and the ductility reduced, particularly at 250° C.

Pure Iron—After treatments at 100°, 200°, and 250° C., an increase in yield stress and a return of a small yield point were found at each temperature. These results were unexpected, as it was assumed that pure iron is non-ageing in character.

Artificial Ageing at Temperatures Below 100° C.

Steels *BQ*, *AK*, and *BL*, representing O.H., basic Bessemer, and aluminium-killed steels, were tested

Table IV

AGEING OF STEELS AT 75° C.

Steel	Time of Ageing	Yield Stress, tons/sq. in.	Yield-Point Elongation Ratio, %	Ultimate Stress, tons/sq. in.	Elongation, on 2 in., %	Hardness, D.P.N.
O.H. rimming (*BQ*), 2·8% reduction	1 year at room temp.	15·9	4·3	21·8	33	107
	As T.R.*	11·5	0	20·4	42	97
	1 hr.	14·3	1·8	20·7	38	102
	3 hr.	14·2	3·8	20·8	38	104
	6 hr.	14·7	2·5	21·2	37	105
	9 hr.	15·2	5·0	21·3	36	106
	12 hr.	15·4	5·0	21·4	35	106
	1 day	15·6	4·3	21·5	34	107
	3 days	15·9	4·9	22·2	35	106
	5 days	16·2	5·2	22·3	34	107
	7 days	16·5	5·1	22·0	32	108
Basic Bessemer rimming (*AK*), 3·0%, reduction	1 year at room temp.	19·8	7·0	25·9	22	135
	As T.R.*	14·1	0	22·9	32	118
	1 hr.	16·8	3·0	24·3	25	128
	3 hr.	17·0	5·1	24·7	24	131
	6 hr.	18·5	8·8	25·2	22	132
	9 hr.	18·8	7·3	25·1	21	133
	12 hr.	19·0	6·9	25·3	22	134
	1 day	19·5	8·8	25·8	22	134
	3 days	19·8	8·9	25·9	23	135
	5 days	19·0	9·5	24·7	24	134
	7 days	19·2	9·0	24·9	23	133
O.H. Al-killed, (*BL*), 3·0% reduction	1 year at room temp.	13·5	0	21·7	39	111
	As T.R.*	12·4	0	21·2	44	106
	1 hr.	12·5	0	21·3	44	106
	3 hr.	12·7	0	21·4	43	107
	6 hr.	12·9	0	21·4	41	108
	9 hr.	13·0	0	21·3	41	110
	12 hr.	13·2	0	21·2	40	111
	1 day	13·4	0	21·3	40	111
	3 days	13·6	0	21·5	39	111
	5 days	13·4	0	21·3	41	111
	7 days	13·5	0	21·5	40	111

*T.R. = Temper-rolled

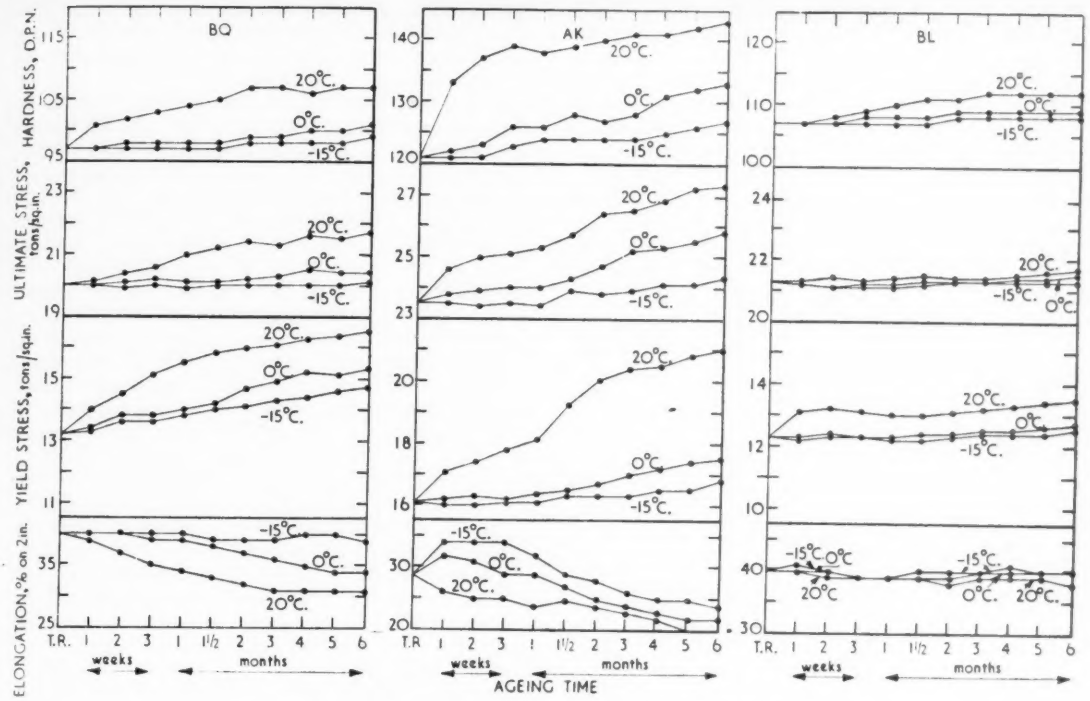

Fig. 4—Ageing tests on three low-carbon steels at room temperature and at low temperatures

after temper-rolling for various times at 50° and 75° C. The results are given in Tables III and IV, and Fig. 3 illustrates the stress/strain curves of the steels after treatment at 75° C. In each case, results for the steels aged for 1 year are given for comparison.

Tests at 50° C. show that the rate of artificial ageing is too slow to serve as a useful rapid test for O.H. and Bessemer steels, as the fully aged values are attained only after treatment for 7 days.

More rapid ageing of the rimming steels occurs at 75° C., and 1 day at this temperature gives results

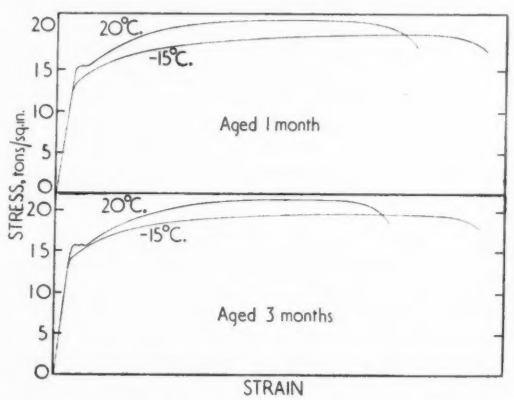

Fig. 5—Stress/strain curves of O.H. steel *BQ* aged at room temperature and −15° C.

that are similar to the fully aged condition. The results remain fairly constant for 3–7 days. A yield point did not return in the killed steel, and the yield stress is closer to that of the fully aged steel.

These temperatures provide a useful guide to the rate of ageing, as shown in the following table for steel *BQ*, a basic O.H. rimming steel.

Normal Ageing at Room Temperature	Equivalent Time of Artificial Ageing	
	at 50° C.	at 75° C.
2 weeks	15 hr.	1 hr.
1 month	2 days	6 hr.
3 months	3 days	9 hr.
6 months	5 days	12 hr.
1–3 years	7 days	24 hr.

Storage at Low Temperatures

The results of the tests after storage at 20°, 0°, and −15° C. are shown in Fig. 4. There is a marked retardation in the ageing of O.H. and Bessemer steels after storage at 0° C., and the properties of the steels are particularly stabilized on storage at −15° C.

O.H. Steel BQ—At low temperatures the yield stress of the O.H. steel increased much more slowly and to a lesser degree than at 20° C. ; the yield point did not return until the steel had been stored for 2 months at 0° C. or 4 months at −15° C. It was indicated only by a slight change in direction in the autographic stress/strain curve, and not by a horizontal step, as found at 20° C. after 1 week. In addition, the ultimate stress and hardness increased only slightly at

0° C. and remained to all intents and purposes constant at −15° C. over the ageing period. The percentage elongation also remained constant for 6 months at −15° C., but decreased slightly after one month at 0° C. In other words, the natural ageing characteristics of the steel were appreciably retarded at 0° C., and almost suppressed at −15° C. for 4 months. Figure 5 illustrates the autographic stress/strain curves of the O.H. steel after ageing for 1 month and 3 months, respectively, at 20° and −15° C.

Bessemer Steel AK—Although the yield stress of the Bessemer steel gradually increased on storage at 0° C. over the ageing period, it was appreciably lower than after storage at room temperature ; it remained almost constant for 3 months at −15° C., and afterwards increased only slightly. A definite return of the yield point occurred in 1 week at room temperature, but a yield point was suppressed for 4 months at 0° C. and 6 months at −15° C. Moreover, the indication of a yield point after cold storage was again represented by only a slight change in direction in the autographic tensile curve, which was appreciably less than that for the steel aged at room temperature for 1 week. A feature of the tests was that the percentage elongation of the Bessemer steel actually increased slightly during storage for 2 weeks at 0° C. or 4 weeks at −15° C. The ductility of the steel did not fall below its original value until it had been stored for 1 and 2 months, respectively, at these temperatures, after which it was reduced at the same rate as at room temperature. The ultimate stress and hardness increased only slightly on storage at −15° C. for 4 months.

Aluminium-killed Steel BL—Cold storage of this steel showed that it was completely stabilized at these temperatures.

DISCUSSION

Although the object of the investigation was to obtain comparative results on mild-steel strip after temper-rolling and ageing in various ways, some comments on the results obtained may be of interest. It has been established experimentally that ageing in mild steel, involving the return of the yield point and a reduced ductility, is due to the effects of carbon and nitrogen. It has been considered that the upper yield point in a tensile test is caused by the extra resistance to plastic flow of the grain-boundary areas, which are strengthened by carbides and impurities. It has been stated[8] that cold work renders the supersaturated solution of carbon in iron more unstable, and that strain-ageing is caused by internal stresses set up by a special kind of precipitation, *i.e.*, in the nature of a stage between a perfect solution and a separation of a distinct phase of iron carbide. A more generally accepted explanation of the yielding and strain-ageing of mild steel after tensile straining has been given by Cottrell and Bilby.[16] Dislocations, anchored by atmospheres of carbon and nitrogen atoms in an annealed mild steel, are torn away from their associated atmospheres, thus giving rise to the upper yield point ; thereafter, plastic flow is caused by the propagation of dislocations at the lower yield stress. Ageing effects involving the return of the yield point are explained by the gradual migration of the solute atoms of carbon and nitrogen towards the dislocations.

Much of the work on the strain-ageing of steel sheet has been confined to stretching in a tensile testing machine. Tests by the authors have shown that, after tensile straining, the changes in physical properties during natural ageing are more rapid than those found after temper-rolling, because in temper-rolling residual stresses are induced in the outer layers of the steel. The effects of cold work and residual stresses are additive, so that the yield point is removed by smaller reductions in temper-rolling than in tensile straining or stretching, in which residual stresses are not induced. Small, rough, and dry rolls are most effective in eliminating the yield-point elongation in mild steel, as a high level of residual stresses is induced in the steel. In contrast to what happens with tensile straining, residual stresses induced by temper-rolling delay the rate of ageing.[15] The dislocation theory is insufficient to explain the removal of the yield point after temper-rolling without consideration of residual stresses.

Figure 1 and Table II confirm that after a light temper-rolling the discontinuous yield point of annealed steel is replaced by a smooth curve, in which yielding commences at a lower value of stress ; this is caused mainly by the effect of residual stresses imparted to the steel. After temper-rolling, a stress gradient extends from the surface to the centre of the steel strip, with tensile stresses in the surface layers and compression stresses in the interior.[19] In a tensile test and in pressing operations, the combined effect of the external tensile stress and residual stresses causes the surface of the steel to yield first where the residual tensile stresses are at a maximum ; yielding then spreads progressively inwards at increasing values of stress.[15, 17] This results in a gradual slope of the stress/strain curve and an absence of stretcher-strain markings in the steel. Tests by the authors have shown that, if the residual stresses in temper-rolled steel are relieved by the application of a small tensile stress, a small yield point is revealed in a tensile test and the rate of ageing is markedly increased.

Ferrite grains in commercial mild steel are supersaturated with respect to carbon and nitrogen, and after straining by stretching or rolling, the solubility of carbon and nitrogen in iron is decreased. Cold work increases the number and movement of dislocations, leaving vacant sites in the disturbed crystal lattice.[20] An increase in yield strength and hardness, and a reduced ductility during ageing are caused by the migration of carbon and nitrogen atoms to vacant sites and dislocations at distorted regions in the crystal lattice, where fine particles of carbides and nitrides are gradually formed. These effects cause a resistance to plastic flow. The more rapid ageing of Bessemer steel compared with O.H. steel is due to its higher nitrogen content. The solubility of nitrogen in alpha-iron is much greater than that of carbon, and as more nitrogen atoms are available for migration, there is a rapid return of the yield point in steels *AK* and *AL*. Strain induced in the lattice by ageing

may be accompanied by micro-stresses in their environment, which may relieve or modify the residual stresses and thus assist the return of the yield point. The rate of ageing is comparatively rapid during the first month, when the solute atoms have a greater freedom of movement than at a later stage, when the migration is restricted. During natural ageing of temper-rolled steels for periods of up to 3 years, the yield-point elongation remains at a low value, whereas it approaches that of the annealed steel on heating to 100–250° C. High values of yield and tensile strength are obtained on artificial ageing, owing to a rapid rate of migration of carbon and nitrogen atoms to complete the formation of carbides and nitrides. These effects are assisted by a reduction in macroscopic residual stresses,[19] which, being noticeably retained in temper-rolled steel on ageing at room temperature, delay the rate of ageing by retarding the migration of solute atoms.

Although the yield strength of the aluminium-killed steels *BL* and *BN* increased during natural ageing, the yield point did not return even after 3 years, but on artificial ageing at 200–250° C. a small yield point was evident. Aluminium additions fix most of the nitrogen in steel *BL* as aluminium nitride, and probably lower the solubility of carbon in ferrite. Small amounts of carbon retained in solution, however, cause an increase in yield strength on natural ageing, but are insufficient to produce a yield point when the residual stresses are noticeably retained. Ugiperval steel *BN*, with a high nitrogen content, had a higher yield strength and lower ductility than steel *BL* after ageing. This is due to the effects of small amounts of uncombined nitrogen, together with carbon. Relief of residual stresses by heating to 200–250° C. causes the reappearance of the yield point in each steel.

The absence of a yield point in the vanadium-treated rimming steel after artificial ageing indicates that vanadium combines with nitrogen to form vanadium nitride, and reduces the solubility of carbon in ferrite to a negligible amount. A small yield point found in the sample of pure iron *BS* after temper-rolling and heating to 250° C. is due to the effects of the solute atoms of carbon and nitrogen and the relief of residual stresses.

The results obtained by artificial ageing below 100° C., *i.e.*, at 50° and 75° C., are more comparable with those found by natural ageing because the residual stresses are not noticeably relieved at these low temperatures. Cold storage of the steels at 0° and −15° C. retards ageing by appreciably reducing the rate of migration of carbon and nitrogen atoms, and by retaining the residual stresses.

SUMMARY

(1) The ageing of low-carbon rimming and killed steels of O.H. and Bessemer origin has been investigated for periods up to 3 years after temper-rolling. Results show that the yield stress of O.H. steel gradually attains the value of the original annealed steel when fully aged at room temperature, but in Bessemer steel it attains a higher value. The yield stress and hardness increase slightly in the aluminium-killed steels after ageing at room temperature, but the steels remain comparatively stable, with no return of the yield point.

(2) The physical properties of the fully aged rimming steels have been compared with those obtained by accelerated or artificial ageing treatments at temperatures of 100–250° C. In the latter tests, high values of yield stress, yield ratio, and yield-point elongation were obtained. The differences between natural and artificial ageing are smaller in Bessemer steel than in O.H. steel, owing to its greater rate of ageing at room temperature. The results obtained have been discussed, with particular reference to the influence of residual stresses.

(3) Artificial ageing treatments of aluminium-killed steels have very different effects from natural ageing, as treatments at 200° and 250° C. show a return of the yield point. The yield stress and yield ratio of these steels are higher than those of the fully aged steels.

(4) There was no return of the yield point in the vanadium-treated rimming steel after artificial ageing, but a small yield point reappeared in pure iron on temper-rolling and ageing at 100–250° C.

(5) The best results on all steels aged at 100–250° C., as compared with natural ageing, was at 100° C., the differences being accentuated at higher temperatures.

(6) Artificial ageing tests at 50° and 75° C. show more comparable results with natural ageing, the speed of which can be followed by heating for various times at these temperatures.

(7) The effect of cold storage of a basic O.H., a basic Bessemer, and an aluminium-killed steel after temper-rolling has been investigated for periods of up to 6 months, and the results have been compared with ageing at room temperature. There was a marked retardation in the rate of ageing in the rimming steels, the properties being particularly stabilized at −15° C. for several months. The aluminium-killed steel was further stabilized by cold storage.

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A Method of Automatic Control for Sinter-Plant Feeder Tables

By S. K. Dean, W. N. Jenkins, P. K. Gledhill, and A. J. Blanchard

SYNOPSIS

The rate of flow of material from a sinter-plant rotary feeder table was controlled by using a Simon constant-weight feeder (a weighing conveyor) to control the table speed. The achievement of a constant rate of flow was indicated by the regular oscillation of the constant-weight feeder weigh-beam about the balanced position. Records of table motor speed show that large speed variations are necessary to maintain constant flow. 924

In continuous sinter plants each raw material is held in a hopper and is fed by a rotary feeder table on to a conveyor belt which passes all the hoppers in turn. The materials then pass through a mixer and are discharged on to the sinter strand. The rate of flow of material on to the conveyor belt is normally set by manually adjusting the position of the plough and the speed of the table. Investigators have stressed the importance of accurately proportioning the mix and have criticized this system.[1, 2]

METHOD OF CONTROL

In some plants the individual feed rates can be adjusted by the strand operator, whilst at other plants they are controlled by the operator in charge of the feeder tables, who sets the feed rate by determining the weight of discharge collected in a tray placed on the gathering conveyor after it has passed beneath the feeder table. With the latter method of control the feed from each table is checked at intervals, and for steady feed conditions it is essential that the discharge should be constant between each check. Also, the composition of the sinter mix is often determined by the crushing-plant programme and it is important that an accurate feed rate from each table can be set, to minimize the changes in mix composition.

The most important variation in feed is due to changes in the physical condition of the material, particularly moisture content, and to changes of the level of material in the feed hopper. These changes alter the angle of repose of material on the table and consequently the amount of material ploughed off. The variation is usually irregular and may be large. It can be eliminated if the feed from the table is continuously measured and automatic adjustments are made to either the plough position or the feeder-table speed.

In an experimental installation at the Cleveland Works of Dorman Long and Co., Ltd., a discontinuous form of automatic control was used in order to keep the control simple. A Simon constant-weight feeder was installed close to the feeder table to detect errors in flow (*see* Figs. 1 and 2). The feeder, shown diagrammatically in Fig. 3, consists of a short belt conveyor incorporating a weighing section where the material is continuously weighed before being discharged over the end. When the weight of the material on the weighing section differs from that required to balance

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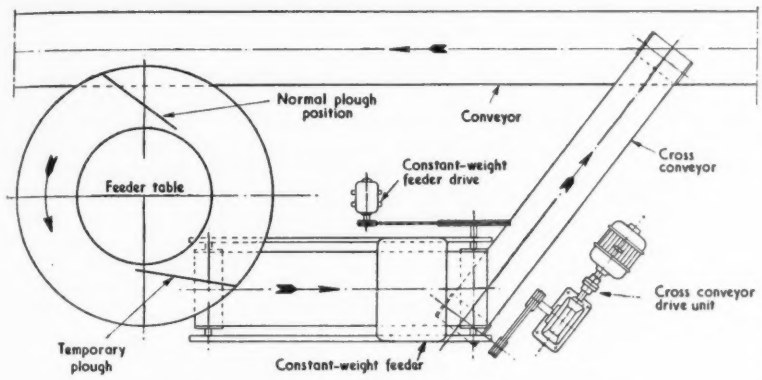


Fig. 1—Diagram of constant-weight feeder installation

the pre-set weight on the weigh-beam, one of two pairs of contacts is closed. The contacts were connected to a control panel (Fig. 4) incorporating a fixed-speed motor which rotated the arm of the field rheostat of the rotary feeder-table motor. Excess weight on the weighing section reduced the speed of the feeder table and a deficiency increased the speed. The rheostat was driven over its full range in $3\frac{1}{2}$ min., that is, one stud pitch in 7 sec. In the working range a change of one stud caused a change in the table motor speed of about 30 r.p.m.

In any closed loop system the speed of correction of errors is limited by time delays, and efforts are made to keep these at a minimum. The time taken for the material to travel from the rotary feeder table to the weighing section was about 3 sec., and when the material reached the weighing section there was a further delay because of the time taken by the material to travel over it. This fact can best be appreciated by considering a sudden increase of delivery from the table. The full effect of this change does not occur until the increase completely covers the weighing section. This delay can be minimized by running the constant-weight feeder at high speed, but the effect of increasing this too much is to make the feeder sensitive to unimportant short-term variations of delivery. A compromise was reached in running the feeder at 60 ft./min.

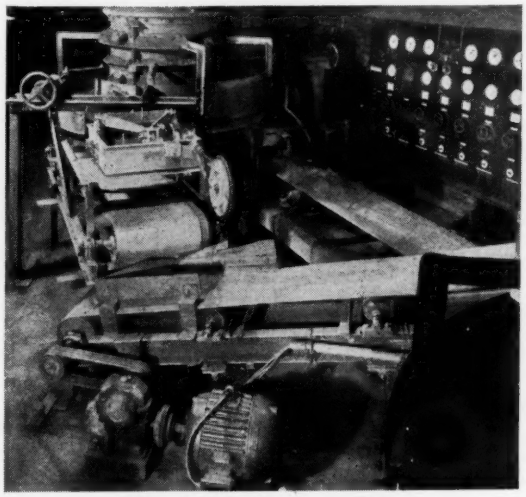


Fig. 2—Installation on site

TRIAL AT CLEVELAND WORKS

A five-day continuous run was carried out with the Simon machine fitted to a feeder table discharging Swedish ore fines at the Cleveland sinter plant. The desired feed rates for the different ores at this plant are determined once each day after consideration of the fines stock and crushing programme, and during this trial the Swedish fines feed rate was required to be maintained initially at 22 tons/hr. and later at 26 tons/hr.

The machine ran continuously during this period, apart from normal plant stoppages and a delay caused by trouble with the belt of the cross-over conveyor. No attention apart from regular oiling of bearings was given to the machine, which withstood satisfactorily the arduous operating conditions of the plant.

The method of investigating the performance of the constant-weight feeder presented some difficulty. The normal method of feed-rate measurement is to place a tray on the gathering conveyor and weigh the material collected on it after it has passed beneath the plough discharge point of the feeder table. Since the material tends to be discharged in small slices from the Simon machine conveyor and the time of collection is only $\frac{1}{2}$ sec., the variation in individual tray weights does not indicate the actual feed-rate variation in the installation. A feature of the fitted control mechanism was that the feeder-table drive motor speed could only be altered in steps of about 30 r.p.m. During the trial the motor speed was approximately 1000 r.p.m.; hence differences of 3% in individual tray weights could be expected.

The accuracy of a constant-weight feeder is usually tested by collecting and weighing the discharge over fixed time periods. Such measurements in other installations have indicated a reproducibility of within $\pm\frac{1}{2}\%$. In this installation, site difficulties and the necessity of maintaining a continuous feed to the sinter plant made this method impracticable. However, since the machine is an accurate weighing device, and the only factor which affects its operation

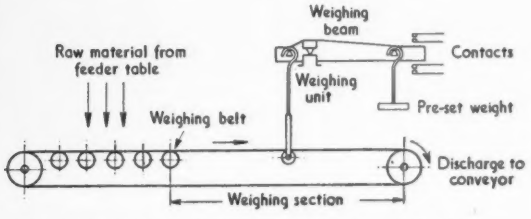
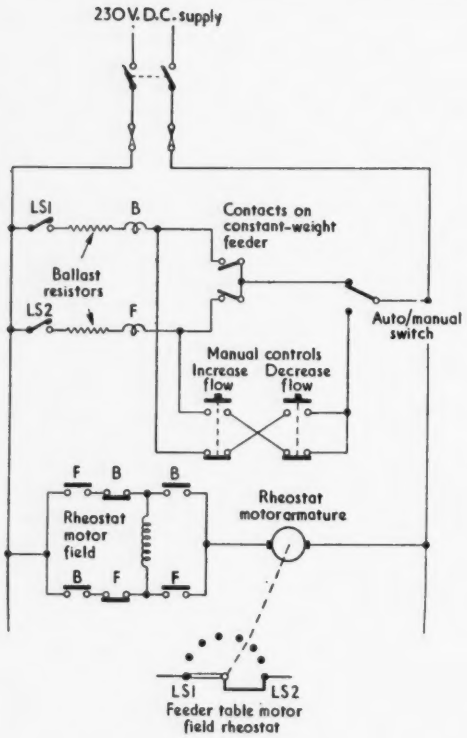


Fig. 3—Diagram of Simon constant-weight feeder



LS1, *LS2*—Limit switches for rheostat travel
F, *B*—Relay coils and contacts for increasing (*F*) and decreasing (*B*) feeder table speed

Fig. 4—Circuit diagram of control panel

is the quantity of material on the weighing section, the sensitivity and degree of balance of the beam is sufficient indication of the closeness of control.

An Everett-Edgecumbe operation recorder was therefore fitted to record the operating time of the 'light' and 'heavy' contact switches of the constant-weight feeder. When the feed rate was close to that required, no record was made; when one switch was closed the time of its closure was the time required to restore balance. A section of this operational chart is shown in Fig. 5. The out-of-balance periods were about 10 sec., with a maximum out-of-balance time of 19 sec. The time taken for the rheostat arm to traverse from one stud to the next was 7 sec. and thus, with the switch closed and the field rheostat motor operating, 7 sec. could elapse before any alteration was made to the speed of the feeder table. There was also a time delay of about 3 sec. before changes in feeder-table delivery were weighed by the machine. Operational times of the order measured represent close control of the feed rate, and when the feed delivered from the table appeared steady the rheostat arm was oscillating between only two studs.

With a fixed plough position the only method of adjustment to counteract the effect of changes in bulk density, moisture content, or arching in the hopper is by variation of the feeder table speed. Hence, if the rate of flow is maintained constant by the constant-weight feeder, the variations in feeder table speed will indicate the degree of control which has been required and the errors which would have arisen if no continuous correcting control was employed. For instance, if the feeder table speed had had to be increased by 25%, then without speed adjustment the feed rate would have been reduced by:

$$\left(1 - \frac{100}{125}\right) \times 100 = 20\%.$$

However, if, under automatic control, the mean feeder-table speed was steady, the normal method of manual setting would have given a constant feed.

A recorder was therefore fitted to the tacho-generator connected to the feeder-table drive motor to give a continuous record of table motor speed throughout the trial period. The record showed that continuous adjustment to the feeder table speed was made by the control, and three main types of feed-rate variation were observed.

With good feed conditions when the mean feeder-table speed was reasonably constant over a period of 2–3 hr., the mean feeder-table speed alternated about $\pm 3\%$; this is shown in Fig. 6*a*. Such variations are probably caused by local variations in material condition and would not affect the sinter process.

The second type of variation observed was a gradual change in the mean feeder-table speed of about 10% over varying periods. Figure 6*b* shows the record obtained when there was a gradual fall in speed over 4 hr., caused by a progressive change in the physical condition of the material. This variation would only be countered manually by very careful checking of the discharge, particularly since the local variations were also present.

The third type of variation was a rapid change of large magnitude which, if unchecked, would have resulted in considerable upset of the sintering conditions. This type of variation occurs when the level of material in the bunker is low or there is arching of material in the bunker. The tacho-generator record corresponding to a period of arching in the bunker

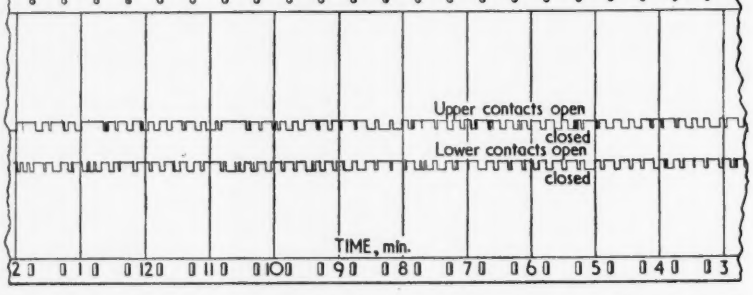


Fig. 5—Part of record of opening and closing of contacts: rate of flow of ore, 26 tons/hr.

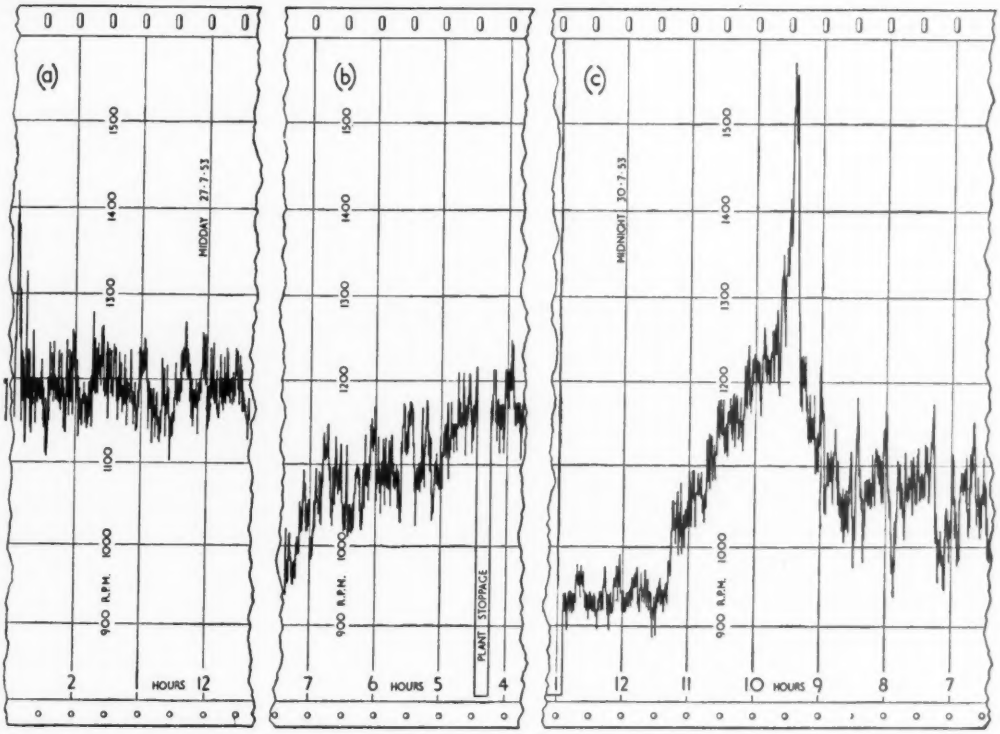


Fig. 6—Parts of records of feeder-table motor speed, showing: (*a*) steady conditions (22 tons/hr.); (*b*) change in physical condition of ore (26 tons/hr.); (*c*) arching of ore in the hopper (26 tons/hr.). Figures in parentheses denote rate of flow of ore

is shown in Fig. 6c. If no correction had been applied the feed rate would have been reduced by more than 20% for about 20 min. This record also shows that even after the arch was destroyed, some 2 hr. elapsed before steady conditions were regained. This type of variation is difficult to counter without automatic control, since the rate of change is usually rapid and the operator is fully occupied in removing the cause of the variation.

The trial was carried out under normal conditions and shows that even with non-sticky ore a constant-weight feeder is essential if the feed rate is to be maintained within $\pm 5\%$. With a sticky ore and with adverse weather conditions the variations in feed rate from a rotary feeder table would be more pronounced, and the incorporation of constant-weight feeders should result in considerable improvement in sintering practice.

CONCLUSIONS

(1) Although there is no direct proof that a constant rate of flow was maintained, the regular oscillation of the weigh-beam about the balanced position indicates that control was achieved.

(2) A change in the mean controlled motor speed of up to 20% in 1 hr. was observed, indicating that variations in flow of this order would otherwise have occurred. Such variations are probably caused by arching or by low mean level of the material in the bunker.

(3) Under steady feed-rate conditions, short-time variations in feeder table speed were $\pm 3\%$ of the mean.

(4) The control was effective over the full range required.

(5) The Simon constant-weight feeder ran without attention for a trial period of five days, during which it passed over 2000 tons of Swedish ore.

Acknowledgments

The authors wish to express their gratitude to Richard Simon and Sons, Ltd., for the loan of the constant-weight feeder, and to Dorman Long and Co., Ltd., for granting facilities to enable the trials to be carried out. They also wish to thank the staff of both companies for their most able and willing co-operation.

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Electron Micrographs of Crystal Boundary and Sub-Boundary Structures in Steels and Ingot Irons

By E. W. Williams, B.Sc., and H. O'Neill, M.Met., D.Sc.

SYNOPSIS

As part of a study of replica materials, micrographs were obtained during the strain ageing and quench ageing of a rimming steel. Straining caused break-up and solution of boundary carbide, so that it disappeared after several days. Subsequent room-temperature ageing produced mottling and finally a dispersed precipitate. The tensile yield point disappeared before solution was completed, and returned during ageing at a stage before the formation of any observable free constituent. Quench ageing gave similar structural features. A specimen of aged Armco iron with boundary double ridges of carbide contained dispersed carbide particles and also sub-grain boundaries which generally consisted of strings of particles. A heat-treated Ni–Cr–Mo steel casting, suffering from intergranular brittleness, contained rounded particles of a constituent along pre-existing grain boundaries. Sometimes these particles were in a band similar to the double boundaries in the Armco iron. Effects associated with nitrogen boundary concentrations are discussed, especially in regard to overheating brittleness in alloy steels. 937

In connection with a study of various materials for making replicas for the electron microscope, samples of Armco iron and rimming steel were used as objects for examination. Particular attention was paid to sub-boundary structures (' veins ') and ageing effects, and the observations made have been brought together in the present paper. A preliminary difficulty is whether α-veining in ferrite may properly be described as consisting of sub-boundary structures. Robin[1] and others indicated that there was a difference between these two, and this distinction has been made in recent work,[2] where isolated so-called veins were removed in Armco iron furnace-cooled after 4 hr. at 900° C., whereas sub-grain boundaries remained. The latter were also unchanged after water-quenching from 700° C. On the other hand, Rawdon and Berglund[3] have stated that veining was not removed by annealing. Northcott[4] found that a long heating in hydrogen above the A_3 temperature caused them to disappear, although this might be due to chemical reaction.

The main work was a comparison of Formvar and collodion as replicating materials and, in general, Formvar was found to be more reliable. In contrast to Wyckoff,[5] it was observed that collodion deforms plastically during stripping, whereas Formvar is more inclined to rupture. Dry-stripped collodion replicas of the pearlite in a low-alloy steel sometimes showed an apparent constituent between the carbide laminæ, but this was considered to be a false effect due to strain markings on stripping. In the technique finally adopted, the Formvar replicas were backed with thick collodion films. Ethyl acetate solvent proved to be as reliable as the conventional amyl acetate for these, and had the advantage of reducing the preparation time to 1 hr.

MATERIALS AND TREATMENTS

Particulars of the steels used for the work are given in Table I.

The first observations concerned ageing effects in rimming steel *A*. Next the sub-boundary effects in Armco irons *B* and *C* were studied, and finally some results were obtained on alloy steel *D*, which suffered from intergranular brittleness. Mechanical polishing was used for the preparation of all specimens, and 60% Au–40% Pd alloy was used in shadow-casting the Formvar replicas.

AGEING EFFECTS IN RIMMING STEEL

Strain ageing and quench ageing in most samples of soft steel are accompanied by changes in yield-point behaviour. This phenomenon has been studied by many investigators, and Polakowski[6] has recently re-examined the concept of brittle internal structures, as first suggested by Kuroda.

Straining was applied to steel *A* by a surface rolling tool. Rolling to a groove depth of 0·016 in. on the 0·25-in. dia. rod was found to be sufficient to remove its yield horizontal during a subsequent autographic tensile test. Results of Vickers hardness tests (20-kg. load) on two zones of transverse sections after various ageing times are given in Table II. Some results on quench ageing are also included.

Hardness tests at the strain-aged surface showed normal increases, and the variations in the core were partly attributed to the effect of internal stresses on the indentations. Bühler[7] has shown that surface-

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Table I
DETAILS OF STEELS USED

Steel No.	Description	Composition, %							
		C	Si	Mn	S	P	N	Ni	Cr	Mo
A	Rimming steel rod: cold-drawn (25% reduction); vacuum-annealed at 920° C. for 40 min.; cooled *in vacuo*	0·08	trace	0·27	0·033	0·025	0·004	...	...	...
B	Ingot iron: annealed in air at 930° C., aged for several months	0·013	0·026	trace	0·005	0·009	...	...	...	...
C	Ingot iron: normalized at 930° C. in air, strained, and aged for 19 years	0·03	0·01	0·02	0·023	0·008	0·003	...	...	...
D	Ni–Cr–Mo casting: annealed at 950° C. for 2 hr., quenched from 880° C., and tempered to Brinell hardness 322 (nominal composition)	0·3	0·35	0·5	0·02	0·025	...	2·0	1·0	0·3

rolled rods may be in tension at the core with compressions at the surface. The quenched specimen aged at 200° C. showed only a slight change in hardness, for published work reveals that, after 1 hr. at this treatment temperature, the steel will generally have passed through its hardness maximum.

METALLOGRAPHIC EFFECTS DURING STRAIN AGEING (STEEL *A*)

The specimens had to be mounted for examination of transverse sections, and mounting plastic with an accelerator at room temperature proved unsatisfactory. Brass mounting blocks were used, but trapped impurities have produced some dirty replicas. Etching was for 45 sec. in 2% nital. Attempts were made to reproduce the same areas after ageing by scratch-marking, but at that time locating techniques had not been mastered and success was not achieved.

The vacuum-annealed furnace-cooled steel *A* showed a white constituent standing proud of the boundary (sometimes continuous, sometimes discontinuous) at most, though not all, of the ferrite grain boundaries. No dispersed constituent was observed within the grains (Fig. 1*a*). Replicas made after the specimen had been standing at room temperature for 50 days showed no pronounced change of structure, the ferrite remaining clear. Incidentally, a more recent publication[8] has reported that a purer steel containing 0·044% of carbon precipitated large carbide particles after specimens air-cooled from 950° C. had aged for 18 months.

Replicas formed within 30 min. after cold-working showed that on the periphery of the rod the boundary carbide in general had become powdered-up into small residues. 'Halation effects,' which appeared along some boundaries, suggested incipient local solution, and there was also a tendency for a mottling effect in the grains (Fig. 1*b*). Subsequent natural ageing for 14 days after straining showed a striking change, for the boundaries were now represented only by diffuse ridge-like bands; slight mottling of the grains had developed, especially in the core of the rods (Fig. 1*c*). Further ageing for 40 and 47 days (Figs. 1*d* and *e*) gave only 'shadow' boundaries (which sometimes contained minute white particles) and slightly mottled grains. Some very fine white dispersed particles noticed in Figs. 1*d* and *e* need further study, as they may be tenacious etch products.

Table II
AGEING RESULTS ON STEEL A

Treatment	Yield Point	Core of Rod		Periphery	
		Vickers Hardness, D.P.N.	Fig. No.	Vickers Hardness, D.P.N.	Fig. No.
Strain-Ageing Tests:					
Vacuum-annealed at 920° C. for 40 min.	Present	96	1*a*	96	1*a*
Vacuum-annealed at 920° C. for 40 min., aged for 50 days	Present	96	...	96	...
Surface-rolled	Absent	98·5*	...	111*	1*b*
Surface-rolled, aged for 14 days	Returns	94	...	120	1*c*
Surface-rolled, aged for 40 days	...	98	1*d*	130	...
Surface-rolled, immediately aged at 200° C. for 1 hr.	Returns	106	1*f*	124	...
Quench-Ageing Tests:					
Water-quenched from 695° C. (air)	...	139*	1*g*	139*	...
Water-quenched from 695° C., aged at 200° C. for 1 hr.	...	140	1*h*	140	...

* Tested immediately

The surface-rolled specimens after ageing at 200° C. for 1 hr. showed no constituent at the boundaries, and there was slight mottling of the grains in some areas (Fig. 1*f*).

The observations are consistent with the view that cold-working has produced solid solution of the boundary constituent, followed by mottling and the development of an extremely fine precipitate on age hardening. The yield point has first returned in specimens which showed neither boundary constituent nor visible precipitate.

METALLOGRAPHIC EFFECTS DURING QUENCH AGEING (STEEL *A*)

After heating the annealed steel in air at 695° C. for 1 hr. and water-quenching, most of the grain boundaries in the core of the specimen appeared as a rather diffuse ridge network, but some contained a constituent which might be undissolved carbide. The possibility of its being partly oxide must not be overlooked, for Kleinefenn[9] has reported that a normalized low-carbon weld which contained braunite eutectoid showed only boundary oxide after quenching from 600° C. and ageing for 12 days. Figure 13 of Whiteley's paper[15] also suggests the possibility of two constituents at the grain boundary of air-cooled Armco iron. In the present work the quenched ferrite is shown in Fig. 1*g*. After heating the quenched specimen at 200° C. for 1 hr. a constituent resembling carbide appeared at the boundaries, together with discrete particles of a similar material in the grains (Fig. 1*h*). Some of the latter were visible under the optical microscope. Mottling was hardly in evidence and in this over-aged specimen the precipitation process is well advanced.

INGOT IRON AND ITS STRUCTURAL FEATURES

Areas of ingot iron *C* were shown by ordinary optical metallography to contain veins, together with occasional double boundaries (Fig. 2*a*) and round globules of oxide. Under the electron microscope, the boundaries after etching in nital appeared as shallow steps ; the veins were raised above the general level of the ferrite and existed as ridges with slopes down each side (Fig. 2*b*). One type of vein ridge contained discrete rounded raised particles, and the boundaries contained either a continuous or discontinuous constituent. In this specimen, which had been aged for 19 years, the ferrite was slightly mottled and contained a large number of dispersed rounded particles, which seemed to be of the same material as that present in the veins. Reference has already been made to the specimen of pure iron (0·044% of carbon, 0·001% of nitrogen) examined by Allen and his co-workers[8] after ageing for 18 months, which also contained large dispersed carbide particles.

Figure 2*c* is one of several examples where a double boundary consisted of two ridges, about 0·3μ apart, each containing carbide particles. Figure 2*d* shows a massive continuous grain-boundary phase into which runs a semi-continuous broad rough ridge with diffuse particles, and which is considered to be a second type of vein. With this type dispersed carbide was not so prominent in the surrounding ferrite.

Armco iron *B* was studied with an objective aperture fitted to the electron microscope, so that enhanced contrast was obtained without shadow-casting of the replicas. The specimens were etched for 30 min. in picral instead of nital. Figure 3*a* shows the apparently large amount of dispersed phase in those ferrite crystals which have etched more deeply than their neighbours. Sometimes the precipitate appeared as platelets lying in several directions. The higher crystals contained instead a faint honeycomb type of structure. In some replicas the dispersed phase had a somewhat triangular shape, as shown in Fig. 3*b* (shadow-cast). Since the triangles are lighter than the matrix they stand proud in the specimen. This large amount of light area is considered to be an exaggerated effect due to the picral etch, which may leave behind undesirable products and thin out the replica so that it acts as a ' bell tent,' where the much smaller amount of actual constituent would be represented by the invisible ' tent pole ' or ' ridge pole.'

The veins generally appeared to be composed of discrete particles, and are considered to be of the same material as the boundary constituent. Perhaps they form when adjacent particles have the same general orientation.

INTERGRANULAR FEATURES IN Ni–Cr–Mo STEELS

A piece from the keel of a H.F. cast-steel block showing intergranular fracture[10] was examined.* This was steel *D* of Table I, and, after polishing and etching in 10% nitric acid plus 10% sulphuric acid in water (three immersions of 30 sec. each), a multitude of small round cavities was visible at a magnification of 50 (Fig. 4*a*), some of which lay along a network. This is believed to represent the original austenite or the delta grain structure. Figure 4*b* (×750) shows part of the discontinuous network, which appears to be due to solution of the globules by the acid. The specimen contained cubic crystals of zirconium nitride, but only rounded particles were associated with the network. Figure 5*a* also shows continuous carbide deposited at the boundaries of three grains. (This is a collodion replica and strain lines were present in the matrix.)

After carefully repolishing the specimen and etching for 13 sec. in 2% nital, replicas were made from a field located near the centre of Fig. 4*a*. Figures 5*b–d* show that the network in some cases is a relatively broad ' band ' of particles, resistant to nital attack and standing proud of the polished surface. Each band somewhat resembled the double boundary observed in Armco iron (*cf.* Fig. 2*c*) and the centrelines of the particles were about 0·7μ apart. Sometimes the particles formed only a single line. The matrix of the steel contained carbide particles produced by tempering, and these were frequently disposed in patterns corresponding with the usual acicular structure.

DISCUSSION AND CONCLUSIONS

(1) The strain-ageing studies have indicated that boundary carbide may be taken into solid solution

* Made available through the courtesy of Mr. J. F. B. Jackson, of the British Steel Founders' Association.

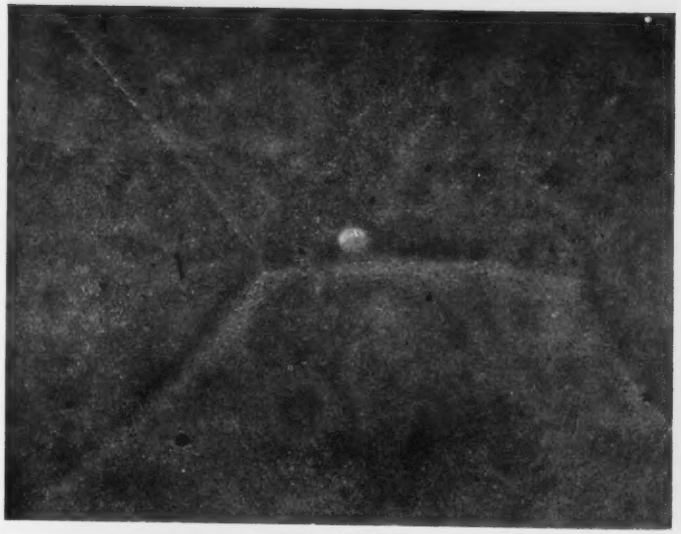
(a) Vacuum-annealed × 11,000

(b) Cold-worked, aged for 30 min. × 11,000

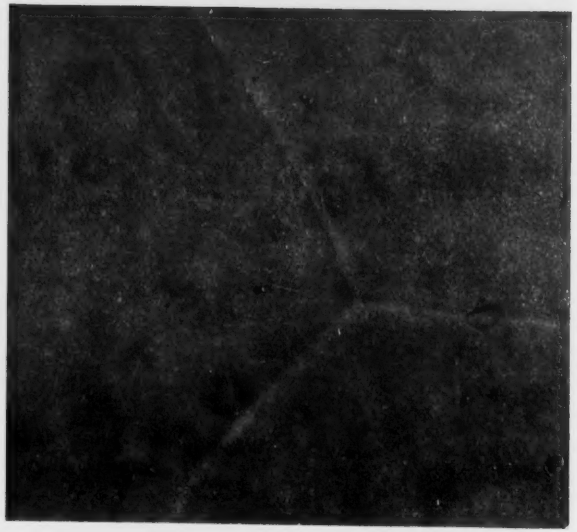
(c) Cold-worked, aged for 14 days × 11,000

(d) Cold-worked, aged for 40 days × 10,000

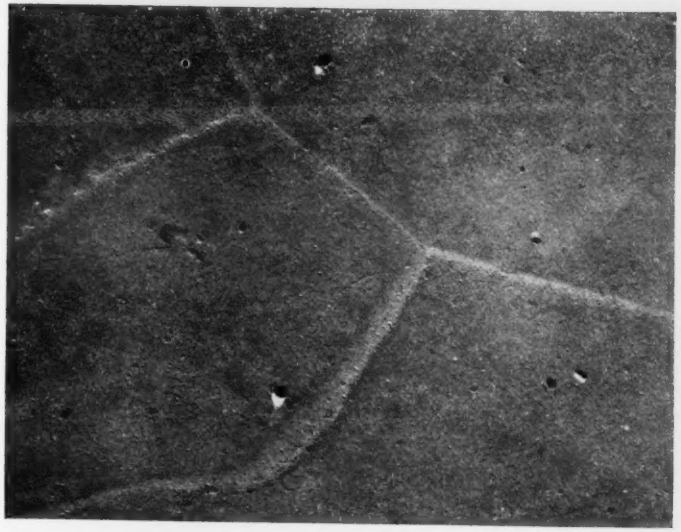
Figs. 1*a–d*—Electron micrographs of steel *A* after various treatments



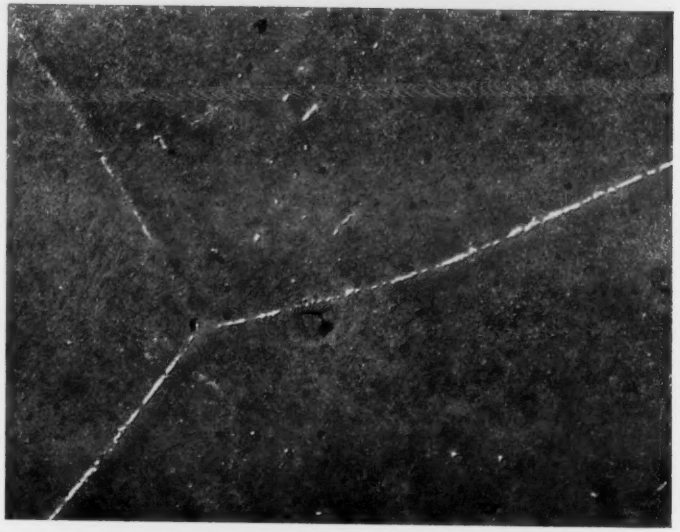
(e) Cold-worked, aged for 47 days × 10,000



(f) Cold-worked, aged at 200° C. × 11,000



(g) W.Q. from 695° C. × 10,000



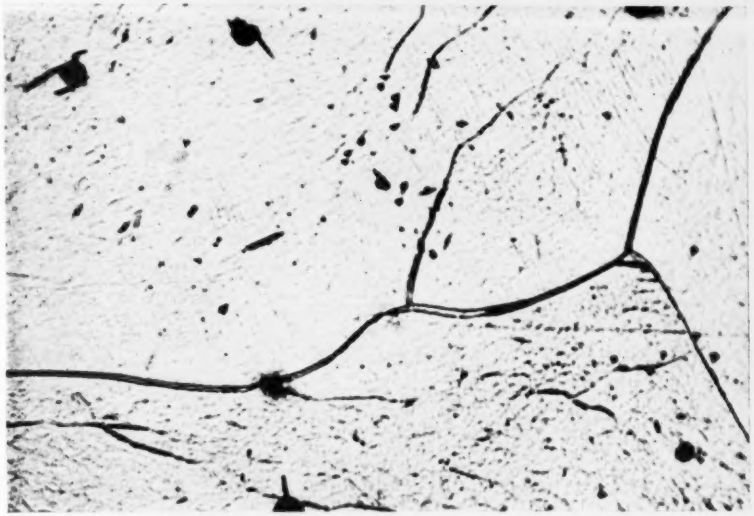
(h) W.Q. from 695° C., aged at 200° C. × 10,000

Figs. 1e *h*. Electron micrographs of steel A after various treatments

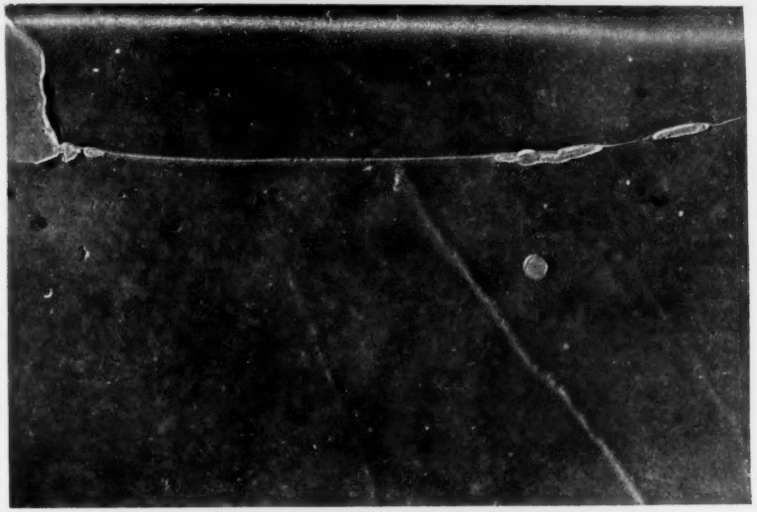
(*g*) W.Q. from 695° C. × 10,000

(*h*) W.Q. from 695° C., aged at 200° C. × 10,000

Figs. 1*e*, *h*—Electron micrographs of steel *A* after various treatments

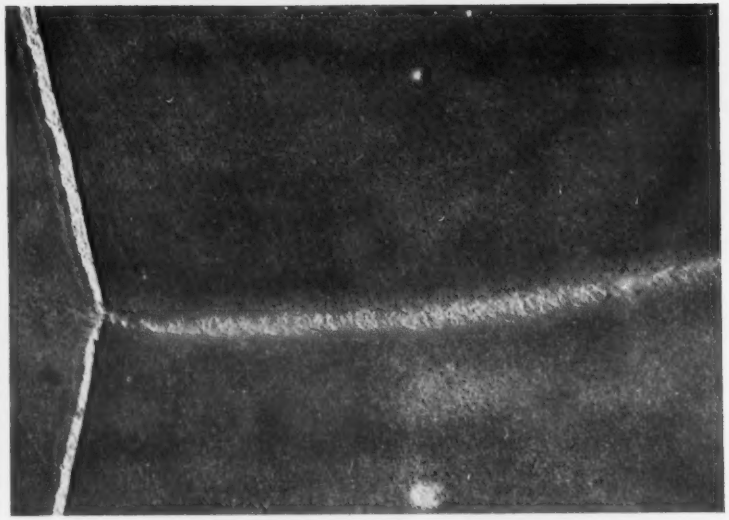


(*a*) × 750 (optical micrograph)



(*b*) × 8000

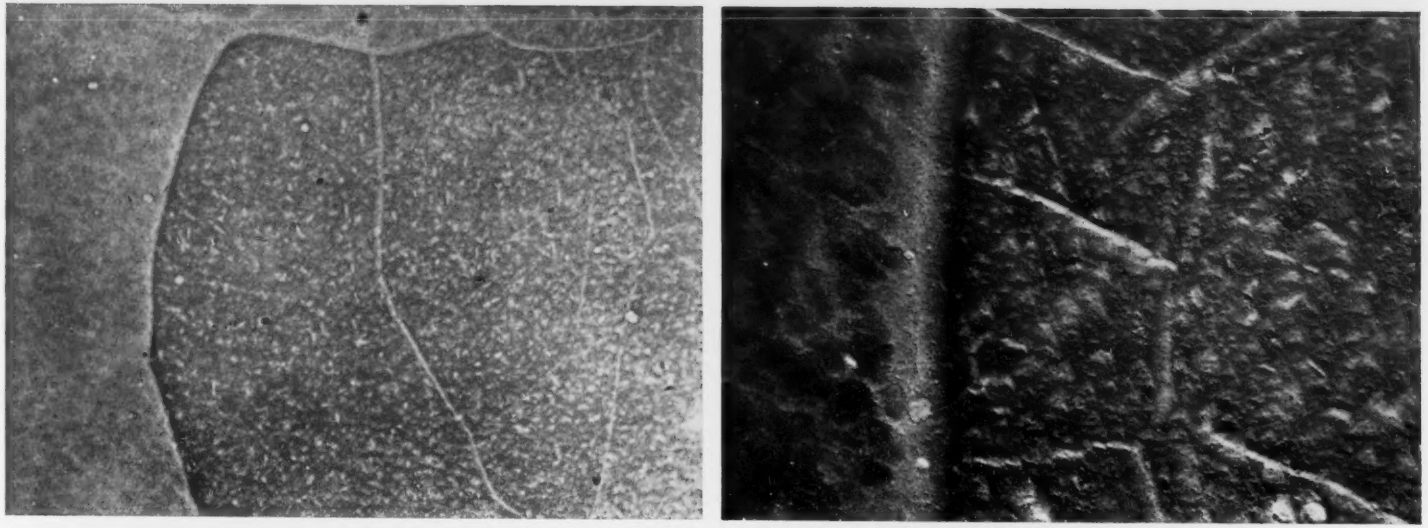
(c) × 8000



(*d*) × 17,000

Fig. 2—Electron micrographs of Armco iron *C*

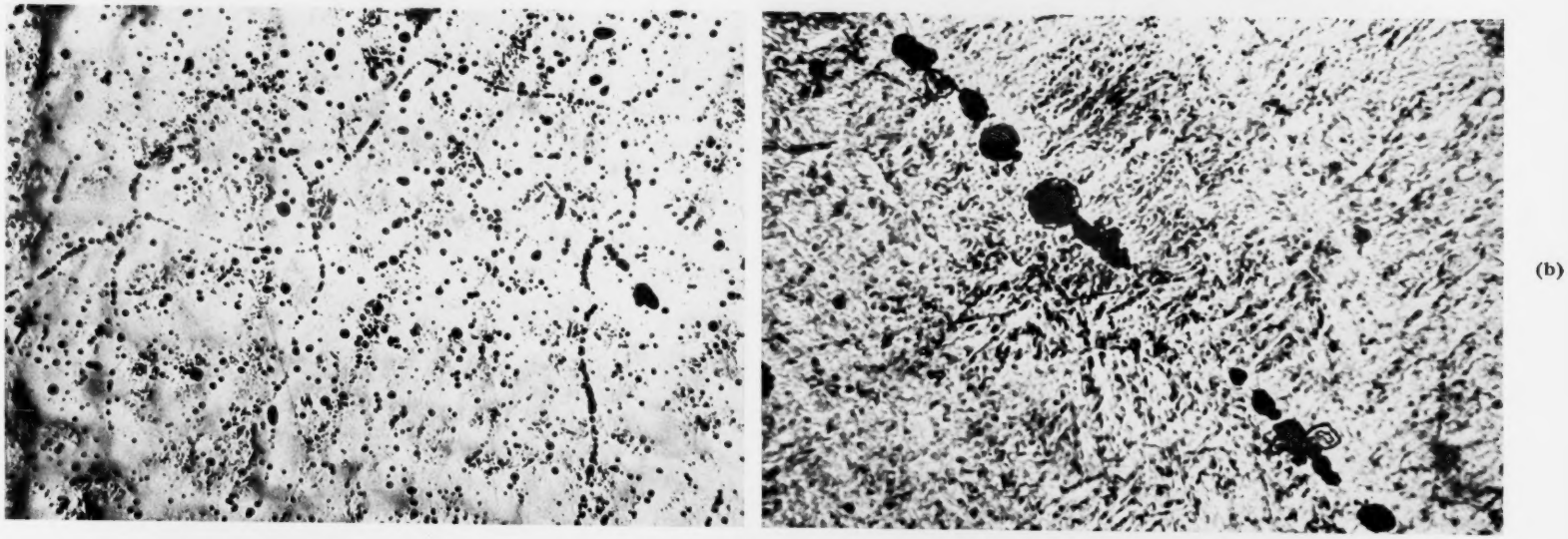
[Williams and O'Neill



(*a*) Plain Formvar replica × 3500 (*b*) Shadow-cast Formvar replica × 25,000

Fig. 3—Electron micrographs of Armco iron *B*

(a)

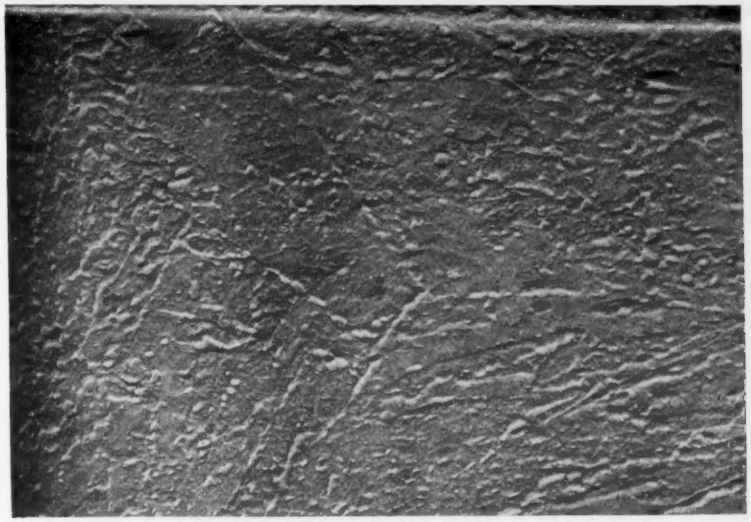


(b)

Fig. 4—Optical micrographs of steel *D*: (*a*) × 50; (*b*) × 750

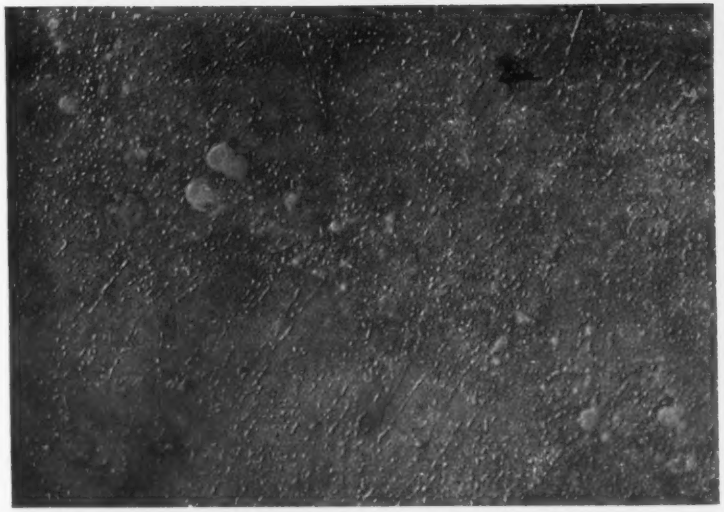
Fig. 4—Optical micrographs of steel *D*: (*a*) × 50; (*b*) × 750

(a)



(b)

(c)



(d)

Fig. 5—Electron micrographs of steel *D*: (*a*) × 12,000; (*b*)–(*d*) × 7500

[W. Williams and O'Neill

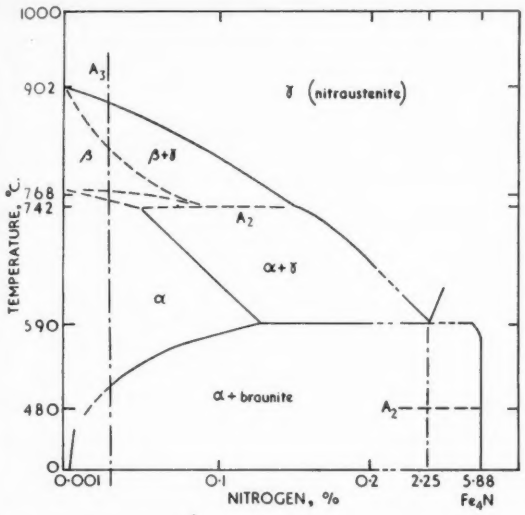


Fig. 6—Tentative Fe–N diagram (after Portevin and Séférian[19])

during room-temperature ageing following cold-working. Andrew and Lee[11] believed that solution by this means required the iron to be changed to the γ form, but, even if this change occurred, it would hardly be expected to persist during the primary ageing period when, according to the present work, the carbon was apparently being dissolved. The results observed are consistent with Cottrell's[12] views that straining increases dislocations, which facilitate migration and solution.

Alpha veining is affected by cold work. Another piece of Armco iron *C*, which had been strained and recrystallized *in vacuo* in 1929, showed an absence of sub-boundaries in those portions which had been most heavily strained. One of the present authors[13] suggested then that "the heavily deformed metal may have solution properties for some constituents present which are not possessed . . . by the less worked metal."

(2) Edwards, Phillips, and Liu[14] decided that the yield-point effect in iron is caused by a precipitated phase. The present results show that yield occurs when no precipitate is visible at a magnification of 10,000.

(3) The dispersed precipitate which occurs in Armco iron on quench ageing had already been shown by Whiteley[15] to migrate readily to ferrite boundaries. Tsou, Nutting, and Menter[2] have proved that it is iron carbide, and that it may collect at sub-boundaries and eventually at boundaries. In the present work, sub-boundaries in α-iron take the form of slight 'ridges,' which were resolved into a 'semi-continuous' phase in some specimens or into a row of discrete particles in others. Where the particles were small, the 'ridge' generally appeared to be broader. The discontinuous veins generally existed in ferrite which contained a dispersed phase. The present authors believe that this phase then migrates to the sub-boundaries and gives the semi-continuous type. No difference of elevation could be seen on either side of the veins, which confirmed that they were not real boundaries. The grain-boundary constituent resembled the vein constituent, and, following Tsou, Nutting, and Menter, would appear to be carbide.

(4) The present authors believe that earlier work on Armco iron, especially on nitrogen diffusion effects, needs to be considered in relation to some of the present work. The well-known 'shortness' in the interval 900–800° C. was reported by Brooke and Hunting,[16] and their specimens quenched in this range showed islands of a eutectoid-like structure surrounded by a diffuse margin. The present authors incline to the view that this structure is associated with nitrogen, for Schuster[17] examined nitrogenized Armco iron (0·02% of carbon) which displayed areas of what he called 'austenite-martensite' after quenching from 580° C. Another of his samples quenched from 910° C. and tempered at 580° C. gave patches of eutectoid surrounded by a halo, which resembles the curious constituent found by Brooke and Hunting.

Bramley and Haywood[18] had previously shown that nitrogenized iron apparently produced austenite when quenched from 700° C. Portevin and Séférian[19] independently discovered the same effect and, by quenching nitrogenized Armco iron from 600° or 800° C., obtained 'nitromartensite', which seems to be the eutectoid-like structure observed by Brooke and Hunting. By quenching from just above A_3, the French workers obtained their 'nitraustenite', which on age hardening produced structures in the ferrite grains which the present authors believe to be the 'veins' recently distinguished by Tsou, Nutting, and Menter in the ferrite of their Armco iron (*see* their Fig. 2*a*). The latter do not mention the earlier work. It is quite consistent, therefore, that by electron diffraction they should have discovered austenite at the crystal boundaries of Armco iron (0·025% of carbon, 0·006% of nitrogen) quenched from 700° C., assuming that nitrogen had segregated to the extent of about 2% as they calculated. Their very pure iron gave no evidence of such austenite, so that Armco-type materials (which have additions of aluminium) seem to be susceptible to migration of nitrogen to the boundaries on heating.

Considering the Fe–C–N ternary at the Fe corner between A_2 and A_3, the Fe–N binary may resemble the disputed portion of the Fe–Ni diagram as determined by Hanson and Hanson[20] on specimens which had actually been heated in nitrogen. In Fig. 6 the diagram of Portevin and Séférian[19] has been modified for discussion purposes.* The (β+γ field) might make a starting point to account for the observations of Brooke and Hunting, assuming that the quenched γ in their case broke down into the eutectoid constituent. The Ac_3 transformation would now require to be a range, and they reported values of 888–941° C.

*When this proposal was mentioned to Prof. F. C. Thompson he recalled the diagram used by Benedicks in connection with the ferronite theory. Reference then showed that the Fe end of the Fe–N system suggested in Fig. 6 was the same as that designed by Roozeboom from the results obtained by Roberts-Austen for the Fe–Fe_3C system.

Other workers (*e.g.*, Harrington and Wood[21]) give an Ac_3 range for Armco iron as 865–910° C. The $(\alpha+\beta)$ field would correspond with the repeated observations of Arnold that Ar_2 was a bulge or double peak (765–745° C.), and in the $(\alpha+\gamma)$ region the French workers found that A_2 occurred at 742° C. The final form of the diagram might have to consider the findings of Dijkstra[22] that precipitation effects due to nitrogen appear to involve a two-stage mechanism.

(5) The presence of double boundaries, which have been resolved into two rows of particles, is a significant feature of the present work. Thermal etching of metals *in vacuo* sometimes produces unexplained ridging on each side of grain-boundary grooves, whereas temper-brittle steels have been shown to give definite channel boundaries on acid etching. The Burgers[23] model for a boundary shows that geometrically the dislocations may be considered as lying along two lines, although the spacing between these is much smaller than that observed in the present authors' double boundaries. A double row of dislocations, however, might act as the locus for duplex zones of solution which, with repeated heatings, might produce backing-up effects, supersaturation, and precipitation.

(6) In connection with the present authors' 'double row' of particles at some of the boundaries in Ni–Cr–Mo steel *D*, the micrographs obtained by Preece *et al.*[24] have been examined. Their Figs. 13 and 14 (×75) of etched overheated alloy steels have signs in places of double-boundary effects, and the overheating had been performed in an atmosphere containing about 78% of nitrogen. In the discussion of this paper one of the present authors (H.O'N.) suggested that observed ease of burning or overheating was directly related to higher nitrogen contents. In the same discussion, Bastien quoted the theory of Portevin that incipient fusion could produce a liquid capillary boundary film which would form 'strings and islets of cementite' on cooling. The present authors believe that something like this has happened to aluminium-treated steel *D*, and that the particles are actually globules and strings of carbide or nitro-carbide, as in the Armco iron. This quenched steel had been reheated to about 625° C., and, after consideration of Fig. 24 in a paper by Keating,[25] it is suggested that the material is a rich compound of chromium, possibly associated with a nitrogen gradient at the boundaries.

Overheating brittleness in Ni–Cr steels gave the impression to Howarth of gas pressure at the boundaries, and in this respect attention may be drawn to the observations of Colbeck and Garner.[26] In their Cr–N alloys veining in the ferrite and globules at the boundaries were sometimes observed, and if the nitrogen exceeded 1% of the chromium content the ingots contained gas cavities due to release of nitrogen on solidification. This fact taken together with the present suggestion of a boundary nitrogen concentration might give results consistent with Howarth's impression. No actual cavities were observed in the present specimens, but they may have been located away from the main source of trouble.

Acknowledgments

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The British Iron and Steel Research Association

SKETTY HALL, SWANSEA

Introduction

THE policy of the Association since its formation has been to set up laboratories in different centres of the steel industry which serve both local firms and the industry as a whole. South Wales, being one of the most important steel producing areas, as well as a most important centre of flat rolling, tinning, and galvanizing, was an obvious choice for one of the Association's laboratories : a research group had been working for the steel industry in the Department of Metallurgy of Swansea University College for 20 years before B.I.S.R.A. was formed. This team, led by Mr. D. Luther Phillips since 1932, had been set up by the South Wales Siemens Steel Research Committee and the Welsh Plate and Sheet Manufacturers' Association, under the Chairmanship of Captain H. Leighton Davies, and was directed by Professor C. A. Edwards of the University. Their research in the college included investigations into the influence of varying cold-rolling and annealing temperatures on the properties of mild-steel sheets, the effect of composition and treatment on the rate of and attack on mild steel, the influence of some special elements on the strain-ageing and yield-point characteristics of low-carbon steels, and some fundamental studies concerning the yield point in steel. They also carried out projects in steel and tinplate works on such problems as the causes of surface defects on tinplate steel, the porosity of tinplate coatings, and the development of electro-tinning as a method of coating. This group became part of the British Iron and Steel Research Association at its foundation in 1945. The staff was expanded, new equipment was acquired, and it soon began to outgrow its accommodation at the University. In 1946, in co-operation with the local municipal authorities, Sketty Hall, a 40-roomed mansion on the western outskirts of Swansea, was leased by the Association (*see* Fig. 1).

Fig. 1—Sketty Hall, Swansea

The Hall, built in its original form in 1749, served until 1939 as a residential mansion for many industrial magnates, the most notable of whom were Sir John Weston Dillwyn, F.R.S., the proprietor of the famous Cambrian Pottery, and Mr. Glyn Vivian, a member of the family which founded the copper industry in Swansea, who stored in the Hall the treasures which later formed the nucleus of the Glyn Vivian Art Gallery in the town. At this historic house the B.I.S.R.A. South Wales laboratories were officially opened in July, 1947.

The research team, under Mr. Luther Phillips, has grown to about 30 and its work is divided into four sections: Electro-Chemistry, Metallurgy, Physics, and Chemistry, under Dr. F. W. Salt, Dr. M. L. Hughes, Mr. T. C. Toye, and Mr. W. Bullough, respectively. Mr. Phillips retired in February this year, and the present Head of the Laboratories is Mr. S. S. Carlisle. The programme of research is concerned with the application of all metallic and other inorganic coatings to steel, and with steel surfaces in general. Since the main object of coating steel is to protect it, and the materials used in the process have recently been both scarce and costly, many of the investigations have inevitably been directed towards securing the maximum protection with the least possible amount of coating. The work includes the study of the steel base and of the coating materials before they are applied, methods of applying the coatings, and the properties of the composite coating produced.

ELECTRO-CHEMISTRY OF COATINGS

The Electro-Chemistry Section is mainly concerned at present with the electrodeposition of iron–zinc alloys. A method has been developed in which iron and zinc are deposited simultaneously on steel sheet, to form an alloy coating whose composition depends on the conditions of deposition and the composition of the coating bath. Alloys have been deposited with zinc contents varying from 3% to 90%. Two examples from within this range will serve to illustrate some of the interesting features of these coatings.

A coating containing about 6% of zinc is nearly as reflective as a perfect mirror. It adheres well to the steel sheet and has a smoothing effect, *i.e.*, the coating is deposited first in the hollows of the steel so that the mirror surface is obtained without buffing on an etched steel plate. The coating can be deposited at the rate of about 0·0001 in./min. and has a hardness

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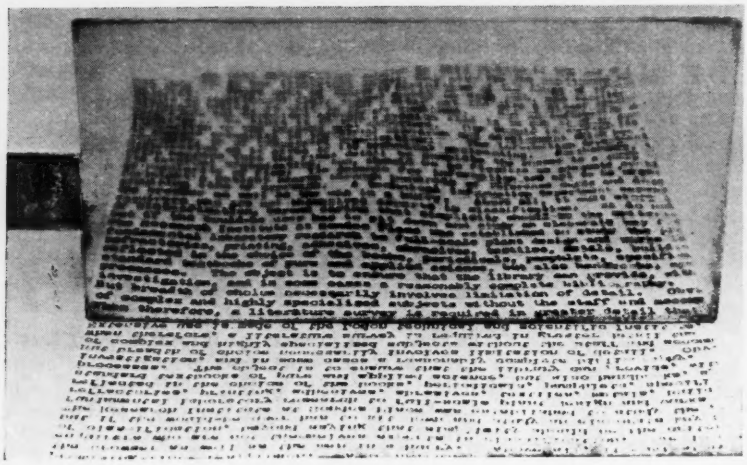

Fig. 2—Reflection by an iron–zinc alloy coating

of 560 D.P.N. The alloy surface does not tarnish indoors, but does not resist corrosion sufficiently well to be used outdoors. An alloy containing 63% of zinc has a lustrous surface and a hardness of about 300 D.P.N., and it can be deposited at about the same rate as the 6% Zn alloy. Preliminary tests suggest that it will resist outdoor corrosion well. A coating of this alloy deposited on a steel sheet has been buffed to a mirror brightness and chromium plated (Fig 2).

Experiments are now being made to determine the best methods of depositing alloys with compositions varying throughout the whole range; when the work is complete, steel sheets will be coated with the alloys under the best conditions for each composition and will be tested for their resistance to corrosion, to find out which compositions give the best protection.

CORROSION IN FOOD CONTAINERS

Another subject recently investigated is the electrochemical behaviour of tinplate when used as a food container. This can be influenced by many factors, the most important of which are discontinuities in the tin coating and the nature of the food packed. A method of assessing the area of steel exposed at pores in tinplate has been tried by the Isotope Division of the Atomic Energy Research Establishment at Harwell, on specimens supplied by the South Wales Laboratories. The tin is immersed in a solution of cobalt salt containing some radioactive isotope. Since cobalt is below iron but above tin in the electrochemical series, deposition of cobalt by chemical displacement occurs only on the iron exposed at the pores in the tin coating. When the treated plate is left in contact with a photographic film, an autoradiograph is produced (*see* Fig. 3). Darkened areas on the plate indicate the presence of radioactive cobalt that has been deposited at the pores. In addition, if the total radiation from a specimen is measured with a Geiger counter and compared with that from a known area of steel similarly treated, the area of steel exposed at the pores can be assessed.

The substances in fruit juices which can corrode tin when there is no oxygen present have also been studied. It is well known that certain fruit packs dissolve tin from the inside of a can, independently of the porosity of the tin, and that for this to occur in a properly evacuated can some depolarizer other than oxygen must be present. Tests with the juices of raspberries and of Victoria and yellow plums have established the presence of a depolarizer which can strip tin coating under anaerobic conditions.

ALUMINIUM COATINGS

A simple continuous hot-dip method of coating steel strip with aluminium has been developed by the Metallurgy Section. Since aluminium coatings can withstand temperatures up to 700° C. or above, Al-coated steel is suitable for use in many industrial processes that require temperatures too high for tin or zinc coatings. Aluminium is generally resistant to corrosion, and if body members of motor or railway vehicles can be coated with it they can be bonded to aluminium body sheets without placing dissimilar metals in contact. Thus, a serious cause of corrosion is removed and at the same time protection is given against ordinary rusting. An example of this is given in Fig. 4. Many other uses are waiting for this material if it can be produced cheaply enough.

Several obstacles have delayed the development of a hot-dip method of aluminizing. A hard and brittle layer of alloyed iron and aluminium is formed at the steel surface, where a soft and ductile coating which can be shaped and manipulated is required. Also, an oxide skin forms on the surface of the aluminium bath and the dipped steel can catch up pieces of this,

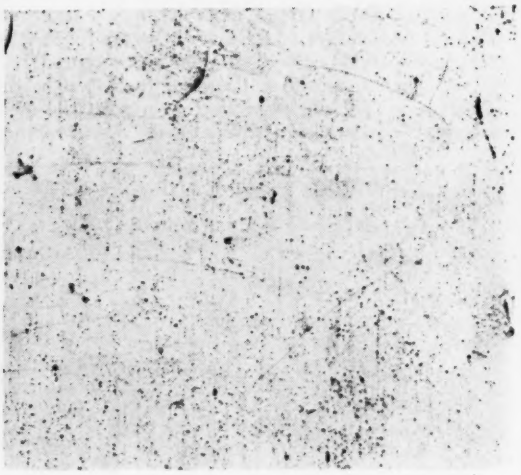

Fig. 3—Autoradiograph of tinplate treated with a solution of cobalt 60

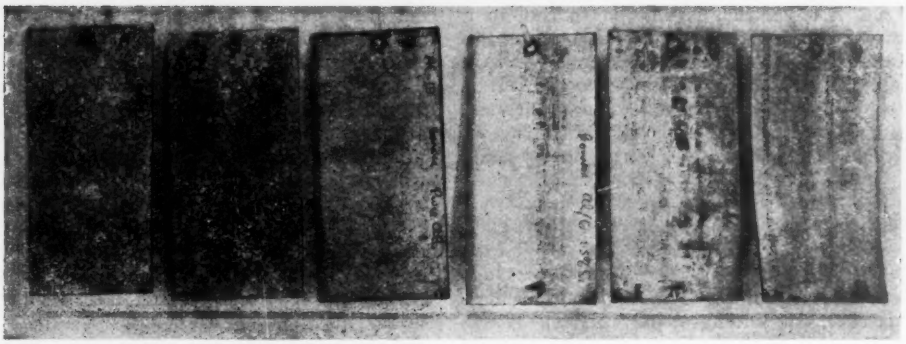

Fig. 4—Galvanized and aluminized panels after exposure to humidity tests for 148 days: (*a*) and (*b*) Galvanized; (*c*) aluminized in pure aluminium; (*d*) aluminized in a 1½% Si bath; (*e*) and (*f*) aluminized in a 3% Si bath

making the surface uneven. It is not pleasant or practicable to work with a molten flux blanket on the bath as in galvanizing; all the fluxes tried caused uncoated spots on the strip, so no flux blanket is used. The brittleness of the coating has been reduced by adding silicon to the aluminium. This method has been used in the U.S.A. for some time. The difficulties caused by oxidation of the ingoing strip have been overcome by a comparatively simple method developed in the Swansea Laboratories. Careful preparation of the steel surface is essential, after which a film of glycerol is applied to it. The strip then enters the bath through a protective box which prevents any of the aluminium oxide film from reaching it, and the glycerol burns quietly, preventing the ingoing strip from oxidizing. In this process, the time and temperature of immersion are such that heavily cold-worked steel can be annealed at the same time as it is coated. In certain cases this may be a great convenience and an economic advantage.

RECOVERY OF ZINC FROM GALVANIZER'S DROSS

The recent shortage of zinc gave an incentive to attempts to save it, in addition to finding substitutes. The Metallurgy Section have developed a novel method for recovering zinc from galvanizer's dross. This metallic sludge, which collects at the bottom of galvanizing pots, can spoil the coating if it comes in contact with it, and the galvanizer has periodically to remove it. In the recovery process the dross, which usually contains about 97% of zinc and 3% of iron, is added, with some aluminium, to a bath of lead, and the whole melt is heated to about 750° C. The iron combines with the aluminium and floats to the surface as an alloy, while the zinc dissolves in the lead. The iron–aluminium compound is skimmed off

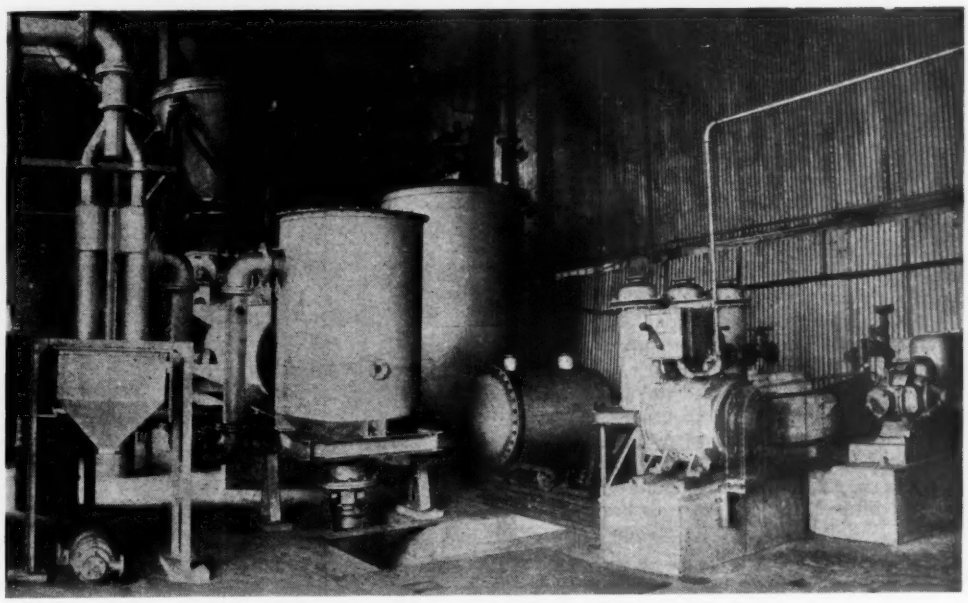

Fig. 5—Pilot autoxidation plant in course of erection

and the zinc–lead solution is allowed to cool to a temperature at which the zinc crystallizes out on top of the molten lead. The zinc is then removed as a solid block, and the lead can be used again. It is possible to recover 95 lb. of pure zinc from each hundredweight of dross. The method, which is comparatively cheap and is simple, can be used in any works.

RECOVERY OF WASTE PICKLE LIQUOR

The shortage of sulphuric acid a few years ago threatened the steel industry with serious difficulties in pickling sheet for tinning or galvanizing. It was this shortage, added to the increasing difficulty of disposing of the waste liquor, that led the Chemistry Section to study methods of regenerating sulphuric acid from it. The shortage is, for the moment, less severe, but may return at any time. Meanwhile, the recent ' pollution of rivers ' act passed by Parliament has made disposal much more difficult, so that the solution of this problem remains most important. The chemists at Sketty Hall have been successful in producing sulphuric acid from waste pickle liquor by the ' autoxidation ' process. A ' pilot ' plant capable of producing the equivalent of 1–2 tons of sulphuric acid per day in the form of weak acid has been built at a member firm's works and is nearly ready for operation (Fig. 5). The liquor left after descaling steel contains a little sulphuric acid and much ferrous sulphate. The steel-works concerned will evaporate their waste liquor to a high acid concentration, so as to precipitate the ferrous sulphate as monohydrate. After filtration, the acid will be returned to the pickling tank and the monohydrate will be used in the autoxidation plant. The process in the plant is then as follows:

The monohydrate is roasted in a rotating stainless steel retort. It gives off a gas containing sulphur dioxide and sulphur trioxide, and leaves a residue of iron oxide which, after sintering, should be suitable for use in blast-furnaces. The gas is atmospherically cooled from 750° to 350° C., and is then further cooled to 40° C., and most of the dust and sulphur trioxide are extracted by passing the gas up a packed tower down which flows cold dilute acid. The resulting hot, dusty, and more concentrated acid is cooled, diluted, and its dust allowed to settle, before it is returned to the tower. The acid made from the sulphur trioxide is tapped off, passed down a stripper to remove its dissolved sulphur dioxide, and finally delivered to a store tank.

The cool, fairly clean sulphur dioxide and air from the tower are mixed together with an excess of air and with the gas from the stripper. The mixed gas is compressed, further filtered to remove the last traces of dust and acid mist, and finally passed into the autoxidation unit. This consists of a multiple diffuser placed in a tank partially filled with water containing a trace of manganese sulphate. On passing through the diffuser, the gas emerges into the water in the form of small bubbles. The oxygen and sulphur dioxide present in the bubbles react in the presence of the manganese catalyst to form sulphuric acid. When the acid concentration is high enough, more water and catalyst are added to maintain this concentration and the excess fluid is allowed to overflow into the store tank, from which it can be withdrawn for pickling.

The Chemistry Section is also investigating methods of preventing steel from scaling during heating. Promising results have already been obtained by spraying a solution of ammonium borate on to the surface of the steel, which has previously been heated to about 150° C. On heating to temperatures up to 850° C. the borate decomposes to a viscous film of boric oxide, which is impervious to oxygen. Quenching in water dissolves the boric oxide, leaving a steel surface entirely free from scale. For temperatures in the range of 1000° C., spraying with a fine suspension of clay has been found to reduce scale formation very considerably.

PHYSICS SECTION

The thickness and distribution of coatings and the studies of the geometrical characteristics of metal surfaces have been under investigation for some time by the Physics Section. Not only does the surface contour of a metal affect the amount of coating that has to be applied, but the roughness or smoothness affects the amount of alloy produced and the relative proportions of the various phases constituting the alloy layer. A most sensitive instrument, the Talysurf profilometer, is used in the Physics Laboratory (*see* Fig. 6). In this instrument a diamond stylus moves over the surface of a specimen, or a replica of it, placed horizontally. The stylus follows the contours continuously and records them on a graph. The vertical magnifications of records taken on the instrument can be varied from 400 to 100,000.

The crystal structure of electrodeposits are examined by an electron diffraction camera. X-ray diffraction is at present being used to determine the texture of rolled and drawn iron and copper strips, rolled copper

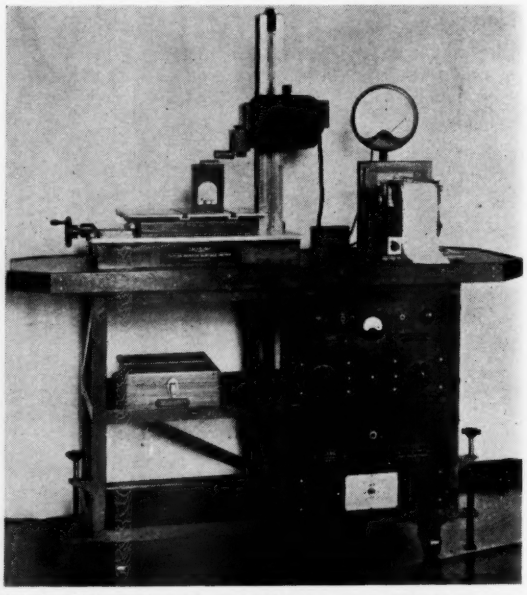

Fig. 6—Talysurf surface-roughness measuring instrument

and copper alloys, and drawn wire. Both cold-worked and annealed samples of 3% silicon-iron have also been investigated. Recently, X-Ray diffraction methods were found to be capable of assessing the amount of temper rolling to which a strip had been subjected.

An extensive study has been made by the Physics Section of the physical properties of molten binary alloys. This arose out of an investigation of a problem concerning the fluidity of commercial galvanizing baths. Measurements of viscosity, density, electrical conductivity, and coefficients of expansion have been made, and it is hoped that the investigation will give a better understanding of metals in the liquid state.

Theoretical study of the hydrodynamics of the hot-dip process has suggested a new method of coating which does not require the sheet or strip to be immersed in molten coating metal. Early experiments show that thinner coatings are obtained by this method than from the hot-dip process; moreover, since one side is coated at a time, it will be possible to apply coatings of different thicknesses to the two sides of the strip.

The research team at Sketty Hall forms part of the Mechanical Working Division of B.I.S.R.A. In addition to coatings, this division is concerned with research on all methods of metal deformation. Of these, rolling, sheet metal working, forging, and wire drawing are investigated in the Sheffield Laboratories. The study of metal surfaces is so closely allied with these deformation processes that there is a continuous link between Sheffield and Sketty Hall on many problems. Another close tie is with the Chemistry Department in London, in whose laboratory many samples of steel coated at Sketty are tested for their resistance to corrosion. The South Wales team also carry out tests for the Metallurgy Division. Close collaboration is maintained directly between the scientists at Sketty Hall and other research associations, among them the British Non-Ferrous Metals Research Association, the Fruit and Vegetable Packing Research Association, and the Zinc Development Association.

A Combustion Method for the Determination of Sulphur in Slag

By the Methods of Analysis Committee

SYNOPSIS

Many factors contributing to the speed and accuracy of the determination of sulphur in slags by combustion have been investigated and a rapid control method suitable for steelmaking practice has been devised. The procedure is simple, but it requires careful attention to detail for successful operation. Some suggestions are made about the objectives of future research on this subject. 914

THIS project arose from work being carried out by the Sulphur Working Party of the Steel Practice Committee, which involved the determination of sulphur partition between slag and metal. Considerable discrepancies were found between sulphur figures from different laboratories, sufficient to invalidate subsequent calculations of sulphur partitions. Investigation of this problem was therefore referred to the Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories Analysis Sub-Committee* of the Methods of Analysis Committee.

As the method was required for control purposes on steelplants it had to be a rapid one. It had also to give results accurate enough to enable the required furnace-control calculations to be made with confidence. It was apparent that an accurate standard method for determination of sulphur in slags was first of all required as a basis against which to compare subsequent figures, and a gravimetric method was therefore developed and tested. A report on this has already been published† and the method itself has been sent to the British Standards Institution as a tentative standard method.

PRELIMINARY WORK

Earlier work on evolution methods for sulphur had shown that reproducible and useful results could be obtained on certain slags by variation of the solution technique. As these slags contained sulphate sulphur and ferric iron, the variations consisted of the addition of reducing agents such as aluminium, tin, and

* The constitution of the Sub-Committee at 31.12.53 was: Mr. G. E. SPEIGHT (*Chairman*), United Steel Companies, Ltd.; Mr. B. BAGSHAWE, Brown-Firth Research Laboratories; Mr. E. W. HARPHAM and Mr. I. HERBERT (left 31.3.52), Richard Thomas and Baldwins Ltd.; Mr. W. H. HESSON, Appleby-Frodingham Steel Co.; Mr. A. P. LUNT, Park Gate Iron and Steel Co.; Mr. D. MANTERFIELD, Steel, Peech and Tozer, Ltd.; Mr. R. PRITCHARD (joined 1.4.52), Shelton Iron, Steel and Coal Co., Ltd.; Mr. N. D. RIDSDALE, Bureau of Analysed Samples, Ltd.; Mr. C. W. SHORT, John Lysaght Ltd.; Mr. J. L. WEST, Hadfields Ltd.; Mr. T. H. WILLIAMS, Stewarts and Lloyds Ltd.; Mr. E. C. V. WISKAR, Dorman Long and Co., Ltd.; and Mr. J. O. LAY (*Secretary*), B.I.S.R.A.

Paper MG/D/136/53 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 13th August, 1953.

† Methods of Analysis Committee, *J. Iron Steel Inst.*, 1953, vol. 174, pp. 28–30.

stannous chloride to obtain complete evolution of sulphur as hydrogen sulphide on solution in hydrochloric acid. On most slags, however, the techniques failed to give satisfactory results. Attention was therefore focused upon combustion methods, variants of which were already in use in some of the co-operating laboratories.

Basic open-hearth and electric-furnace slags often contain fluorine from fluorspar additions, and it was evident that in such cases acid–alkali titration would give rise to error. This interference was confirmed by a series of tests using three variations of the absorption and titration technique:

(i) Water and iodide–iodate
(ii) Silver nitrate and sodium hydroxide
(iii) Hydrogen peroxide and sodium borate.

Both the acid–alkali titration methods gave very unsatisfactory figures when compared with gravimetric determinations, whereas the iodide–iodate technique showed promise.

As these slags can also contain calcium and barium sulphates, the decomposition of these compounds under combustion conditions was investigated; it was found that at a temperature of 1300° C. these substances could be decomposed and complete recovery could be obtained by iodometric titration. It was also shown that calcium phosphate did not interfere with the results obtained.

This preliminary work cleared the way for a detailed examination of the combustion method with an iodometric finish, during which the following points have been discussed and investigated in detail:

(i) Blank correction
(ii) Combustion temperature
(iii) Oxygen flow
(iv) Apparatus and analysis train
(v) Yield
(vi) Standardization.

DEVELOPMENT OF THE METHOD

Blanks

A considerable amount of work was carried out to determine the true blank on the method. Some of the early determinations had shown discrepancy in blank titres on standard steels, standard slags, and distilled water. This was found to be due to a combination of at least two factors: varying yield and blank titre. The blank titrated under the conditions of the determination naturally included that due to boats and tubes in addition to that due to reagents.

Tests were made, therefore, using standard solutions of sodium thiosulphate and sulphurous acid with varying quantities of starch, hydrochloric acid, and potassium iodide present during the titration. It was appreciated that the starch end-point was sluggish in the absence of sufficient potassium iodide, and this was finally proved to be the chief reason for some unduly high blank titres.

The use of pretitrated water was examined, but was abandoned in favour of pure distilled water. The use of pretitrated water may involve the risk of negative error from overtitration. Subsequent blank determinations on the plain water absorbent, with controlled amounts of potassium iodide, starch, and hydrochloric acid, indicated a reproducible titre within 0·05 ml. The small blank arising from this source becomes incorporated in the overall furnace and reagent blank, which is of the order of 0·2 ml. of the titrant. This is automatically compensated in slag analysis by the similar value deducted for the steel added as a flux.

In this connection the possibility of pre-oxidation by the release of iodine from excess potassium iodide was examined. Although no confirmatory evidence was obtained, it was thought that under certain conditions of acidity and excess reagent this could produce a further error when using pretitrated water. In all these tests the highest blank was obtained under conditions of high acidity, low starch addition, and the absence of potassium iodide in the absorbent during titration. The controlled conditions laid down in the method result in a small and reproducible blank.

Temperature

A temperature of 1330–1350° C. was finally laid down as the optimum range for reproducible and accurate determinations. A series of tests had shown that low and erratic figures were obtained at 1200° and 1250° C. The upper limit of 1350° C. is approaching the point at which the boats, covers, and/or thimbles would fail. It was felt that, if refractories were available to stand up to, say, 1450° C. under these conditions, this higher temperature may result in yields more closely approaching the stoichiometric.

Oxygen Flow

A flow rate of 0·75–1 l./min. is recommended as giving reproducible results. Low flow rates (less than 0·5 l./min.) result in incomplete combustion in the time specified. High flow rates give incomplete absorption of the SO_2, overheating of the tube, and, with flow rates higher than $1\frac{1}{2}$ l./min., actual loss of the absorbing water. It was also demonstrated that high rates of oxygen flow through very dilute solutions of sulphurous acid can result in SO_2 being removed from the solution.

It is thus necessary to have a calibrated flowmeter in circuit to measure and control this flow. An instrument of the pressure-difference type is recommended, and details of this and a method of calibration are given in Appendix II.

To ensure the best conditions for complete absorption a tall vessel 10 in. high × $1\frac{5}{8}$ in. internal dia. is suggested, and the volume of water used is 200 ml. (low volumes of water can give incomplete absorption). The water should be cold, because the solubility of SO_2 in water decreases with increase in temperature.

As a further aid to complete absorption, a bubbler of the type shown in Fig. 1 is recommended. Sintered-glass bubblers are unsatisfactory, as they tend to be attacked by fluorine compounds from the slag and clog rapidly.

Apparatus and Analysis Train

The furnace and analysis train are very similar to those in general use for combustion sulphur on steels and other materials. Several items call for special comment in slag analysis. The bubbler, flowmeter, and absorbing vessel have been mentioned in the previous section.

A special furnace should be reserved for slag

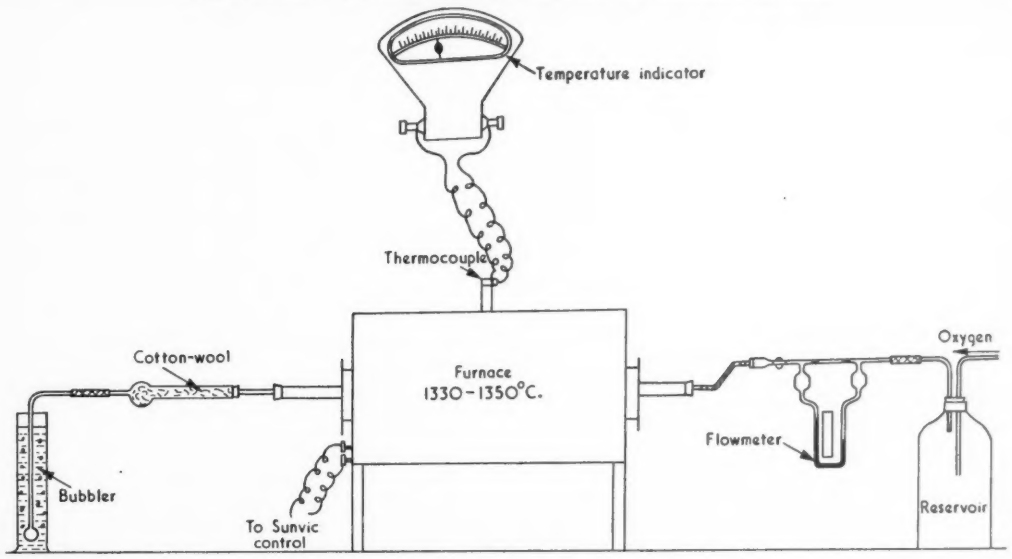

Fig. 1—Simplified diagram of apparatus

sulphurs. Any undue contamination of the tube or delivery end by iron oxide from steel determinations, for instance, would affect the accuracy of subsequent slag analyses.

Trials were made to compare boats and covers with thimbles. There appears to be no significant advantage in the use of thimbles, and there may be some disadvantage in the insertion of the slag, accelerator, and tin powder in a thimble. The use of boats and covers is therefore given in the method, with thimbles as an alternative. Either should be pre-ignited before use to eliminate blanks.

The use of the cotton-wool filter was investigated. Tests carried out without this filter necessitated preheating to avoid the carry-over of iron oxide. Unlike cast iron and high-carbon steel determinations, the use of preheat and dispensing with the cotton-wool filter showed no advantage, and there was some evidence of earlier failure of the boats or thimbles. As the method was intended for rapid control purposes it was recommended that a cotton-wool filter be used, without preheat. The cotton-wool should be dried and stored in a desiccator until required. The filter should be changed frequently.

Some experiments were carried out using a second absorbing vessel. With high rates of oxygen flow some SO_2 was found in this second absorber, but with the rate of flow specified it was unnecessary.

Yield

Although all the conditions have been standardized as far as possible, varying yields have been obtained by different operators and by the same operator on different occasions. Some obtained higher yields with a new tube, which gradually decreased with further use of the tube; others did not have this experience. This variation, however, applied to the standard as well as the sample under test, and the final results by all operators were in close agreement. An average yield of 80% has been assumed.

Any further work in this direction would involve intensive precision work in producing a stoichiometric version of the method. Since the original intention was to produce a rapid reliable control method and since an examination of stoichiometry is already in progress elsewhere, it was felt that no additional investigation of this question was desirable.

Standardization

In the course of this investigation a standard steel has been used. Certain other alternatives, such as a standard slag and pure sulphur-bearing reagents, have been examined, but it was agreed that a standard steel provided a basis for factor assessment which is valid for slags under the conditions laid down in the method. The basis of comparison for accuracy of results using such a steel factor was their agreement with gravimetric results.

A high-sulphur steel might be desirable, but some doubt was expressed about the homogeneity of such steels, and a standard steel containing 0·04–0·05% of sulphur was considered to be satisfactory. A steel standard is easier to obtain and use than a standard slag and probably introduces less error, owing to the precision with which results can be reproduced.

The method is entirely empirical in its present form and, bearing in mind the variation in yield previously mentioned, frequent standardization is necessary. One standard for every five to six determinations is recommended, although the yield does not vary as rapidly as this suggests. With this safeguard concordant results are obtained with great regularity.

Other Considerations

In addition to the items already mentioned, several other details require attention. To minimize error a very low sulphur standard steel is recommended for use as an accelerator. This should be in the form of sawings or fine millings. In the present series a steel of 0·014% sulphur content was used.

Table I

SLAG SULPHUR DETERMINATION USING DRAFT METHOD

	Sulphur, %			
Analyst	MGS/133	MGS/101	Parkgate 1	Parkgate
1	0·335	0·18	0·47	0·54
2	0·345	0·175	0·495	0·58
3	0·33	0·17	0·48	0·58
4	0·345	0·18	0·475	0·575
Gravimetric	0·345	0·175	0·49	0·565

As stated in the method, the starch solution should be 10 g. of soluble starch to 400 ml. of boiling water, 5 ml. of this solution to be used in each determination. It may be an advantage to add 0·1 g. of thymol per 100 ml. of starch solution as a stabilizer.

It is essential to have enough potassium iodide in the absorbing solution before commencing titration and the addition should be equivalent to 0·1 g., *i.e.*, 10 ml. of a 1% solution. The acidity should be controlled and 10 ml. of hydrochloric acid (1 : 4) is recommended for this purpose; to obviate any possibility of pre-oxidation the three reagents should be added in the order given.

The inclusion of a blow ball to wash out the delivery tube on completion of absorption is also convenient and advantageous.

FINAL TRIALS

After the detailed investigation described, a draft method was prepared and applied to four slag samples. The results are given in Table I, together with the accepted gravimetric figures. A further series of slags examined by other members of the Sub-Committee using the suggested method gave the results shown in Table II. These results were considered satisfactory and the method is put forward as an acceptable rapid control method.

FURTHER WORK

This investigation into the rapid determination of sulphur in slags has naturally involved more than a cursory glance at the combustion sulphur method as a whole. To make the method truly stoichiometric would involve far more work than was included in the terms of reference for the present project and would entail lengthy, precise, and fundamental research into many aspects of the determination of sulphur in a wide range of materials. The thermodynamics of sulphur, SO_2, SO_3, and oxygen would need close examination with the object of converting all the sulphur into a measurable form (most probably SO_2). The question of the ' missing ' sulphur, the absorption and retention of the SO_2 in water or other medium, the need to add an accelerator such as steel or tin, and the use of gases other than oxygen (*e.g.*, CO_2, air, or various mixtures of oxygen and nitrogen) would all need investigation. A step forward has already been made by the B.I.S.R.A. laboratories, as reported elsewhere,* and private work has been done in this direction in one or two laboratories, with promising results.

One important feature has been shown to be the speed and temperature of combustion. At higher temperatures (1400–1450° C.) the yield approaches the stoichiometric, even when the sample is burnt in oxygen, but new refractories are required for tubes and boats or thimbles when working at this temperature.

* C. J. B. Fincham and F. D. Richardson, *J. Iron Steel Inst.*, 1952, vol. 172, pp. 53–55.

Table II

SLAG SULPHUR DETERMINATION USING SUGGESTED METHOD

	Sulphur, %				
Analyst	MGS/130	MGS/131	MGS/132	MGS/133	MGS/101
5	0·39	0·28	0·22	0·34	0·19
6	0·40	0·27	0·19	0·34	0·18
7	0·40	0·27	0·215	0·345	0·18
8	0·38	0·27	0·20	0·33	0·18
9	0·41	0·27	0·21	0·335	0·18
10	0·40	0·27	...	...	0·19
Gravimetric	0·40*	0·28*	0·215	0·345	0·175

* By one member only

CONCLUSIONS

This method is designed as a purely routine method for a particular purpose. Although the results obtained are satisfactory and reproducible, it is not stoichiometric in its present form and reproducibility depends upon strict adherence to the operating conditions laid down in the method. Undoubtedly a certain amount of experience and manipulative skill is also required before the best results can be obtained.

The question of differences in yield and hence of factor assessment has been discussed earlier. In spite of such differences, however, the calculated sulphur results in each case show good agreement and, as a result of prior information given to the Sulphur Working Party of the Steel Practice Committee, the method is being used successfully by their chemists. The information on standardization and blanks included in the present paper should help materially to ensure a greater measure of agreement between experimental results.

Detailed fundamental examination of the combustion sulphur method would be desirable, and work along these lines is in progress, but a complete understanding of the processes must be considered as a long-term objective and should not be permitted to delay the completion of useful short-term investigations.

APPENDIX I

Recommended Combustion Method for Determination of Sulphur in Basic Steelmaking Slags

Principle

A sample of the slag, together with standard low-sulphur steel millings or sawings and a small portion of tin powder, is ignited at a temperature of 1330–1350° C. The products of combustion are passed into distilled water absorbent and titrated with potassium iodide–iodate solution using starch as indicator.

Apparatus Required

Combustion Furnace—This consists of a normal arrangement of heating elements and insulating bricks

with a central orifice carrying the combustion tube, to which is attached the oxygen supply and absorption train. The furnace should be capable of giving a temperature of 1350° C. along a minimum length of 7 in. Silit and Globar heating elements have been found to be satisfactory.

The combustion tube should be of impermeable refractory material, such as aluminous porcelain or mullite, 26–30 in. long × $\frac{7}{8}$ in. internal dia., with or without a reduced exit end (Note 1).

Oxygen Supply—The train at the input end from the oxygen supply consists of a large bottle, which acts as a reservoir and assists in maintaining a steady oxygen feed, and a calibrated flowmeter (*see* Appendix II). An oxygen purification tower containing silica gel or soda asbestos may be included if desired.

Absorption Apparatus—At the exit end a tube containing dried cotton-wool is fitted (Note 2), followed by a delivery tube and bubbler into the absorbing vessel. The type of bubbler recommended is that shown in Fig. 1, with a perforated bulb end and no skirt.

The absorbing vessel is 10 in. high × $1\frac{5}{8}$ in. internal dia., capable of holding about 250 ml. of water.

Combustion Boats or Thimbles—Boats are of unglazed porcelain $2\frac{3}{4}$ in. × $\frac{1}{2}$ in. × $\frac{3}{8}$ in., with suitable covers of the same material. An alternative is a thimble $1\frac{5}{8}$ in. long × $\frac{3}{4}$ in. external dia. It is recommended that tube and boats or thimbles should be pre-ignited before use.

Solutions Required

Potassium Iodide–Iodate—Dissolve 1·12 g. of potassium iodate, 10·8 g. of potassium iodide, and 1·0 g. of potassium hydroxide in 1000 ml. of distilled water. This is the ' stock ' solution. For use, dilute 100 ml. of the stock solution with 500 ml. of distilled water. This solution should be frequently standardized against a steel standard of known sulphur content (0·04–0·05%) during a series of tests.

Hydrochloric Acid (1 : 4)—200 ml. of hydrochloric acid (sp.gr. 1·16) diluted to 1 l. with distilled water.

Distilled Water (Note 3).

Starch—10 g. of starch shaken with a small amount of water. Pour this into 400 ml. of boiling water and add 0·4 g. of thymol.

Potassium Iodide (1%)—1 g. of potassium iodide dissolved in 100 ml. of distilled water.

Sampling

Select a representative sample of the slag and crush to pass through a 60-mesh sieve. Any steel shot present should be retained on the sieve. Magnetic separation should be carried out with discretion, as certain slags are themselves magnetic.

Procedure

Weigh 1 g. of low-sulphur steel millings (Note 4) and spread evenly over the length of the boat (Note 5). Weigh 0·25 g. of slag and spread evenly over the steel millings. Dust the whole sample with 0·05 g. of tin powder and place the cover on the boat.

Transfer the boat and its contents to the hot zone of the combustion tube and adjust the oxygen to maintain a flow between 0·75 and 1 l./min. Continue the oxygen flow for 5 min. Rinse the interior of the bubbler by means of the blow ball (if this is not fitted, disconnect the bubbler and rinse into the absorption vessel with distilled water), and rinse the outside with distilled water.

Add 5 ml. of starch solution, 10 ml. of potassium iodide solution (1%), and 10 ml. of hydrochloric acid (1 : 4), in that order. Wash the solution into a clean conical beaker (Note 6) and titrate to the permanent blue end-point with potassium iodide–iodate solution (Note 7).

Calculations

The percentage of sulphur in the slag is:

$$(a - b) \times 4 \times c$$

where a = Iodide–iodate solution used in determination, ml.

b = Iodide–iodate solution used for low-sulphur steel accelerator, ml.

c = The equivalent of 1 ml. of iodide–iodate solution in terms of percentage of sulphur on 1 g.

Notes

(1) The delivery end of the combustion tube and associated rubber cork (if used) can be kept cool, *e.g.*, by water circulating through an external metal coil or dripping on to a cotton-wool wrapping.

(2) The cotton-wool filter should be dried and stored in an airtight container until required. The cotton-wool in the train (which should be loosely packed) requires changing frequently, and it is advisable to clean out the whole apparatus at intervals.

(3) The distilled water should have a negligible ' blank ' and should be kept cool during the determination, as the solubility of SO_2 decreases rapidly with rise of temperature.

(4) The steel used as accelerator should be of a known low-sulphur content and in the form of sawings or fine millings.

(5) When thimbles are used instead of boats, prepare an intimate mixture of 1 g. of low-sulphur steel accelerator, 0·25 g. of slag, and 0·05 g. of tin powder and insert into the thimble.

(6) Titration in the absorption vessel may be preferred to avoid possibility of loss of SO_2 by agitation. No serious error is introduced, however, by careful transfer to a conical beaker before titration.

(7) Steels of known sulphur content or slags on which sulphur has been carefully determined gravimetrically may be used as reference standards.

APPENDIX II

Laboratory Flowmeters

In the course of the work in connection with the determination of sulphur in slags it became apparent that a controlled and measured supply of oxygen over a comparatively narrow range of flow was necessary.

Several types of flowmeter were available and it was desirable to choose the most suitable for this specific purpose. After trials with the surgical type and a pressure-difference type the latter was recommended as being the most satisfactory.

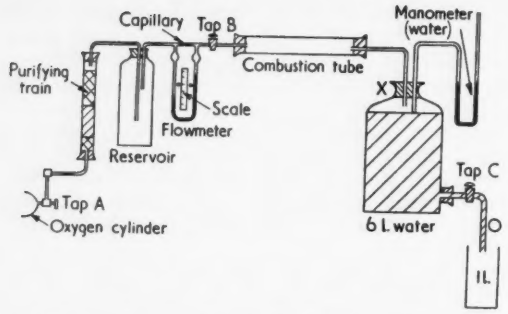

Fig. 2—Calibration of pressure-difference type flowmeter under conditions of free flow

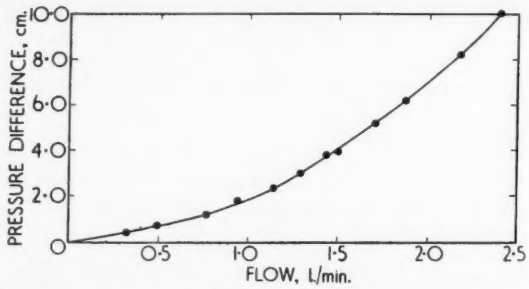

Fig. 3—Typical calibration curve of pressure-difference type flowmeter

As these flowmeters cannot be pre-calibrated, except in a few special cases, it was realized that a recommended method of calibration was also desirable.

General Principles

The pressure-difference type measures the pressure drop caused by a throttling device (such as a nozzle, orifice, or Venturi tube) in the gas supply line. This pressure difference can be calibrated in terms of gas flow.

The British Standard Code on Flow Measurement (B.S. 1042 : 1943) sets out the principles of design, installation, and use of pressure-difference devices in great detail. This code covers the mathematical and physical principles involved and, if all the factors were measurable or known, a meter could be designed and constructed for a specific purpose. The type usually used for laboratory work consists of a manometer tube, with a suitable scale bridged by a capillary. The manometer measures the pressure difference caused by the restriction of the capillary.

There is a quadratic relationship between the pressure difference and the gas flow and, as stated in the B.S. Code, " Small percentage errors in measuring pressure difference correspond to about half the percentage errors in the flow measurement." The size of capillary and the liquid used in the manometer tube affect the sensitivity of measurement and determine the length of scale obtainable over a given range of flow.

Many factors (*e.g.*, the temperature and density of the gas, the form of the supply line, and the regularity of the capillary) affect the standardization and calibration of such an instrument (*see* B.S.1042: 1943). Each flowmeter also has its own particular characteristics exerting their effect on certain constants in the theoretical equations of flow. In the particular case under consideration resistances in the combustion train, especially those close to the outlet end of the flowmeter, may have some modifying effect on the pressure-difference readings. Hence it is considered necessary to calibrate each instrument under conditions as close as possible to those under which it will function.

Calibration

The comparison of flowmeter readings with measured volumes of water displaced over measured periods of time provides a useful starting point for a simple calibration method. Various apparatus schemes are possible, but only a few of these do not involve taking into account a head of water in the displacement vessel.

After some experimental work, a procedure of measurement under free flow was adopted, which is illustrated in Fig. 2. This consists of a flowmeter in circuit at the inlet end of the tube with a large aspirator bottle fitted with a manometer tube at the outlet end. A cylinder is also provided for measurement of the displaced water.

Although it is simple, it may be informative to describe the procedure, which can be followed by reference to Fig. 2.

(1) Begin with cork X out, tap C closed, tap A closed, tap B open, aspirator full, and outlet tube O leading to the waste vessel.

(2) Open tap A to give a small pressure-difference reading on the flowmeter.

(3) Simultaneously open tap C and fit in cork X; make a rough control on tap C to bring the manometer levels about equal.

(4) Carefully adjust tap C to bring the manometer levels correct (*i.e.*, atmospheric pressure).

(5) Simultaneously place the 1-l. measuring cylinder under outlet O and start a stop-watch.

(6) Adjusting tap C to keep the manometer levels equal throughout the process, note the time for 1 l. to flow from outlet O. Note the flowmeter reading.

(7) Remove cork X, close tap C, and refill the aspirator. Re-adjust tap A to give a different flowmeter reading and repeat the process. Carry out this procedure until values covering the whole scale of the flowmeter are obtained. Plot a graph relating flowmeter readings to flow in l./min. An example is given in Fig. 3.

Conclusions

It is considered that the pressure-difference type of flowmeter is the most satisfactory for the laboratory work in question. Choice of capillary and fluid in the **U**-tube will give an open scale which can be read with accuracy. Calibration of each individual instrument is necessary under the conditions of use, and a simple method is suggested as being suitable for the purpose.

An Investigation of the Combustion Method of Sulphur Determination in Ferro-Alloys and Complex Steels

By the Methods of Analysis Committee

SYNOPSIS

A procedure for the determination of sulphur by combustion is described. The method is not stoichiometric, but reproducible results can be obtained by standardization against steels of known sulphur content. The procedure is shown to be applicable to a wide range of materials, including highly alloyed steels and the ferro-alloys of vanadium, tungsten, and chromium, but not that of molybdenum. Up to 16% of molybdenum in steels shows only minor interference. 915

THE determination of sulphur in steels may be carried out by direct combustion in oxygen, absorption of the evolved gases in a suitable reagent, and titration of the resulting solution. The main criticism of this procedure is that, although the yield of sulphur is constant under given conditions, it is not quantitative. The sulphur content must therefore be calculated with reference to suitable standard steels, whose sulphur contents have been established gravimetrically.

Research is in progress with the object of achieving quantitative recovery of sulphur, but meanwhile it is considered desirable to propose a standardized technique with the object of achieving better agreement between laboratories using a combustion procedure. The investigation described has been carried out by members of the B.I.S.R.A. Highly Alloyed Steels and Ferro-Alloys Analysis Sub-Committee.*

RECOMMENDED METHOD

The recommended procedure is described in full in the Appendix. The combustion gases are absorbed in hydrogen peroxide and titrated with sodium borate. This is preferred to the alternatives of absorption in silver nitrate solution and titration with standard alkali or of titration with standard iodine after absorption of the sulphur dioxide in water.

Important features of the procedure are as follows:

(i) Accurate control of the oxygen flow rate

(ii) Thorough ignition of boats and tubes before use and frequent cleaning of the apparatus

(iii) The incorporation of a rubber hand aspirator to facilitate effective rinsing of the inner parts of the delivery system

(iv) Preheating of the sample in the hot combustion zone with the oxygen supply shut off. This causes the sample to frit or sinter, and when subsequent combustion takes place after admission of oxygen there is practically no entrainment of fine ferric oxide dust with the exit gases. This is an important factor, as iron oxide carry-over, which is a normal feature of the conventional process, fouls the exit end of the system. This reduces the yield by fixing sulphur gases as relatively stable compounds in the cooler parts of the system and necessitates frequent cleaning

(v) A proper choice of flux or accelerator, *e.g.*, fluxing with iron in addition to tin, is necessary for the effective combustion of materials such as ferrochromium.

EXPERIMENTAL DETAILS

In a preliminary investigation of the stoichiometry of the procedure, four steels were examined in each of nine co-operating laboratories, and the following ranges of results were reported in terms of millilitres of *N*/200 sodium borate per gramme of sample (1 ml. ≡ 0·008% of sulphur on 1-g. sample).

Sample	Range of Readings, ml.	Sulphur, %
MGS/64 (mild steel	4·85–5·9	0·049
MGS/156 (mild steel)	6·1–6·9	0·058
MGS/157 (cast iron)	2·85–3·9	0·031
MGS/158 (free-cutting mild steel)	25·3–29·6	0·237

When a steel of known sulphur content was used to calculate an empirical factor, however, all results were close to the average figures quoted in the last column. Trials were then made to ascertain the best fluxes to use for a wide range of compositions. The results given in Table I were obtained.

Samples MGS/50*A* and 174 were burnt without flux, but the remainder did not give satisfactory results and so powdered tin was added to obtain the reported figures. For samples MGS/17*B* and 175 the use of pure iron was found to be advantageous.

Since molybdic oxide may be carried over in the gas stream and may interfere with the end-point, a

* The constitution of the Sub-Committee at 31.12.52 was: Mr. B. BAGSHAWE (*Chairman*), Brown-Firth Research Laboratories; Mr. C. D. ATKINSON (joined 1.4.52), Sheffield Testing Works Ltd.; Mr. E. DYKE (left 31.3.52), Brown-Firth Research Laboratories; Mr. W. T. ELWELL (left 1.4.52), I.C.I. Ltd., Billingham Division; Mr. J. W. FLINT (joined 1.4.52), William Jessop and Sons, Ltd.; Mr. L. E. GARDNER, Edgar Allen and Co., Ltd.; Mr. C. L. GRAYSON, English Steel Corporation, Ltd.; Mr. E. W. HARPHAM, Richard Thomas and Baldwins Ltd.; Mr. S. HARRISON, Kayser Ellison and Co., Ltd.; Mr. J. D. HILL, Bragg Laboratory, N.O.I.D.; Mr. G. M. HOLMES (joined 1.4.52), London and Scandinavian Metallurgical Co., Ltd.; Mr. R. T. POSTLETHWAITE, Samuel Fox and Co., Ltd.; Mr. L. N. TAYLOR, Samuel Osborn and Co., Ltd.; Mr. J. L. WEST, Hadfields Ltd.; and Mr. J. O. LAY (Secretary), B.I.S.R.A.

Paper MG/D/135/53 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 13th August, 1953.

Table I

RESULTS BY FINAL METHOD AND EFFECT OF FLUX

Laboratory	Sulphur, %					
	MGS/17*B*	MGS/50*A*	MGS/63	MGS/117	MGS/174	MGS/175
1	0·015	0·038	0·018	0·014	0·043	0·010
2	0·014	0·036	0·016	...	0·045	0·009
3	0·013	0·037	0·017	0·013	0·042	0·010
4	0·017	0·039	0·020	0·012	0·044	0·010
5	0·015	0·038	0·019	0·012	0·043	0·012
6	0·015	0·040	0·019	0·013	0·045	0·013
7	0·017	0·040	0·021	0·013	0·044	0·011
8	0·018	0·040	0·017	0·012	0·046	0·012
9	0·013	0·041	0·019	0·011	0·046	0·009
10	0·014	0·037	0·015	0·015	0·045	0·009
Average	0·015	0·039	0·018	0·013	0·044	0·010

MGS/17*B* = 18/8 Cr–Ni stainless
MGS/50*A* = High-speed substitute
MGS/63 = 30/20/1½ Ni–Cr–Ti
MGS/117 = Ferrotungsten
MGS/174 = Ni–Cr–Mo steel
MGS/175 = Low-carbon ferrochromium

sample of steel with a high molybdenum content was included in a further series of tests on more complex materials. The results are given in Table II.

Various fluxes were examined, including iron, vanadic oxide, tin, and manganese steel. Sample MGS/114 gave the same yield with and without flux, tin alone was found to be satisfactory for most of the other samples, but the high-carbon ferrochromium was completely fluxed only by using a tin–iron mixture. For the high-sulphur steel with 0·2-g. sample weight, the addition of low-sulphur steel to give a total sample weight of 1 g. gave more consistent results. Gravimetric determinations were made on some of the samples examined to afford a basis of comparison.

The influence of molybdenum was also examined using synthetic samples, when it was shown that the equivalent of up to 20% of molybdenum had little effect on the titration of a standard 0·058% sulphur steel. On a ferromolybdenum of 0·08% sulphur content, however, results between 0·05% and 0·09% of sulphur were obtained, molybdic oxide being carried over to such an extent as to make observation of the end-point difficult.

Table II

RESULTS OF TESTS ON MORE COMPLEX MATERIALS

Laboratory	Sulphur, %				
	MGS/59	MGS/114	MGS/148	MGS/185	MGS/193
1	0·025	0·066	...	...	0·041
3	0·027	0·071	0·073	0·64	...
4	0·030	0·067	0·075	0·64	0·042
5	0·027	0·075	0·077	0·63	...
6	0·023	0·077	0·077	0·63	...
7	0·028	0·075	0·075	0·63	0·045
8	0·031	0·076	0·080	0·63	...
9	0·026	0·072	0·082	0·65	0·047
10	0·021	0·068	0·072	0·67	...
Average	0·026	0·072	0·076	0·64	...
Gravimetric	0·023	0·069	...	0·64	...

MGS/59 = High-carbon ferrochromium
MGS/114 = Ferrovanadium
MGS/148 = Alcomax magnet alloy
MGS/185 = Free-cutting stainless
MGS/193 = 16% Mo steel

CONCLUSIONS

Although the combustion method for sulphur in steel is not stoichiometric, reliable results can be obtained by careful attention to operational details. Many ferrous materials can be burnt without the use of flux, but an addition of tin is necessary with high-chromium material. Ferrochromium requires a mixture of iron and tin for complete combustion, particularly when associated with a high carbon content. The procedure is not applicable to ferromolybdenum, but it can be used for steels containing up to 16% of molybdenum.

APPENDIX

Recommended Method

Apparatus

Oxygen Supply and Purification—The general assembly is as shown in Fig. 1. Oxygen of at least 99·5% purity, free from carbonaceous matter, should be used. A pressure-difference (Venturi-type) flowmeter, accurately calibrated to register oxygen flows in the range 2–4 l./min., is incorporated in the system at *E* and a rubber hand aspirator at *F*. A three-way stopcock *B* permits the oxygen supply to be by-passed from the combustion system to a mercury valve *D*. The oxygen is passed from the cylinder *A* through a tower *C* packed with silica gel (¼ in. mesh) between glass-wool plugs and is then conducted to the combustion tube *via E* and *F*, connections being made with rubber pressure tubing (¼-in. internal dia.).

Combustion Furnace and Tube—The electric combustion furnace must be capable of providing a temperature of up to 1400° C. along a minimum heating length of 7 in. No specific type need be used, but the furnace should consist of a normal arrangement of heating elements and insulating material with a central horizontal orifice carrying the combustion tube. The following heating elements have been found to be satisfactory:

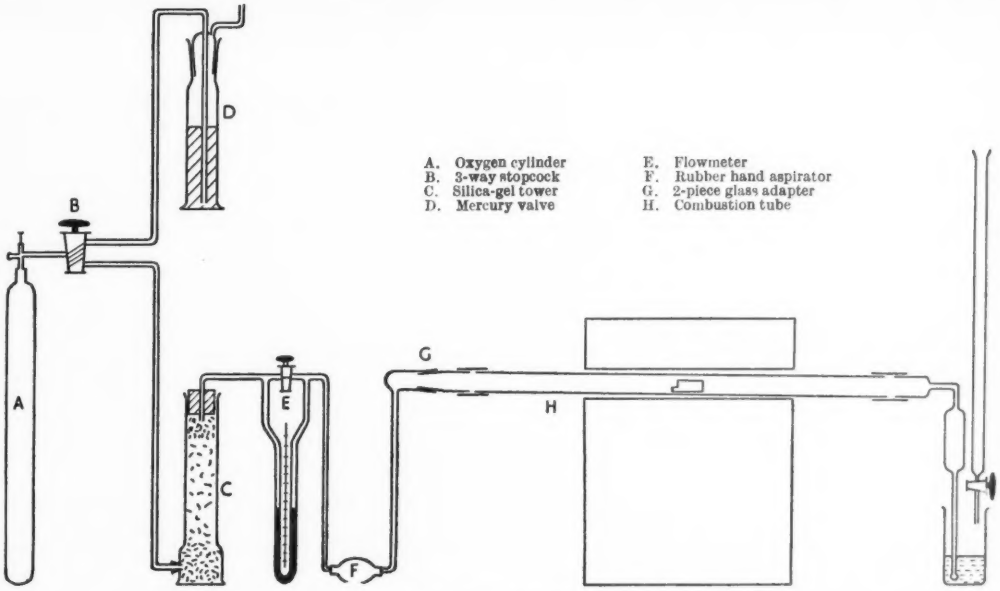

Fig. 1—General arrangement of combustion apparatus

(i) Silit rods
(ii) Globars
(iii) Platinum wire.

The combustion tube *H* should be of highly refractory non-porous material (*e.g.*, aluminous porcelain or mullite) 26–30 in. × $\frac{7}{8}$ in. internal dia. The two-piece glass adapter *G* (Fig. 2*a*) consists of a *B*29 ground-glass joint with a side-arm for oxygen supply, and is attached to the combustion tube as shown in Fig. 2*b*. A glass adapter (Fig. 2*c*) is fitted to the exit end of the tube.

The combustion boat (Fig. 3) is an enclosed fireclay 'thimble' $1\frac{5}{8}$ in. long × $\frac{3}{4}$ in. external dia. This type of boat provides the best conditions for combustion, and it gives more efficient protection against spraying than a boat with a loose-fitting lid, although the latter may be used if desired.

New tubes should be passed through the hot zone of the furnace in such a manner as to enable the entire length to be heated to 1300° C. for at least 15 min. Boats should be heated under oxidizing conditions at 1300° C. before use.

Absorption Apparatus—A glass safety bulb (25–50 ml. capacity) is fitted immediately before the gas distributor tube, as in Fig. 1. Recommended forms of gas distributor tubes designed to ensure intimate contact between the gas stream and the absorbing solution are shown in Fig. 4.

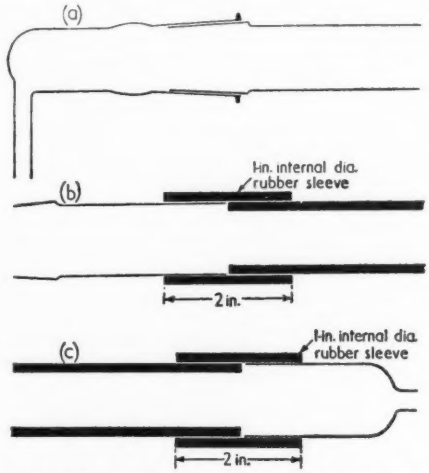

Fig. 2—(*a*) *B*29 ground-glass joint; (*b*) assembly of inlet end; (*c*) assembly of exit end

Solutions Required

Hydrogen Peroxide (1 vol.)—Dilute 50 ml. of hydrogen peroxide (20 vols.) to 1 l.

Sodium Borate (*N*/200)—Dissolve 0·9536 g. of pure sodium borate ($Na_2B_4O_7.10H_2O$) in water and dilute to exactly 1 l.

Sulphuric Acid (*N*/200 approx.)—Dilute 50 ml. of approx. *N*/10 sulphuric acid (3 ml. H_2SO_4, sp.gr. 1·84, per litre) to 1 l.

Indicator—Dissolve 0·083 g. of methylene blue and 0·125 g. of methyl red in 100 ml. of ethyl alcohol.

Procedure

Adjust the furnace temperature to within the range 1300–1320° C. (Note 1). To the absorbent vessel

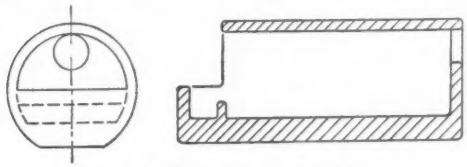

Fig. 3—Combustion thimble

(100-ml. tall form beaker) add 40 ml. of hydrogen peroxide absorbent and assemble the exit end of the apparatus. The gas distributor tube must be immersed well below the liquid surface and as near to the bottom of the beaker as possible without actually touching it. Regulate the oxygen flow to 2–2½ l./min. Add 0·2 ml. of indicator and titrate the solution with $N/200$ sodium borate to the change point of the indicator. Adjust with sulphuric acid ($N/200$ approx.) and sodium borate ($N/200$) until the solution is neutral. Lower the absorbent vessel so that the delivery tube just dips below the surface of the absorbent.

Weigh 1 g. (Note 2) of clean fine drillings or millings and transfer to the combustion 'thimble.'

By-passing the oxygen stream through mercury trap *D* by means of tap *B*, insert the boat directly into the hottest part of the combustion tube and replace *G* (Fig. 1). Preheat for 3 min. (Note 3). Raise the absorption vessel so that the delivery tube almost touches the bottom of the vessel and, by means of tap *B*, readmit the oxygen supply to the combustion system. The oxygen supply remains at its original flow rate of 2–2½ l./min. and is not further adjusted during the combustion period. This just maintains a positive flow through the absorbing solution during the active period of combustion.

The end of active combustion is indicated by a return of the normal gas flow through the absorbing solution; from this stage allow a further 2 min. to sweep the system and expel CO_2 from the absorbent.

Titrate with sodium borate ($N/200$) to an approximate end-point. By-pass the oxygen to the mercury trap and then, by means of the rubber hand aspirator, rinse the interior of the delivery tube and the glass bulb with the absorbing solution. Readmit the oxygen supply and continue the titration with sodium borate ($N/200$); make the final adjustment to the change point of the indicator after repeating the rinsing operation to remove the last trace of acid from the bulb and delivery tube.

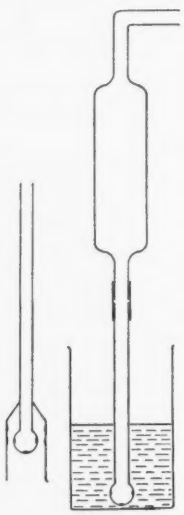

Fig. 4—Gas distributor tubes

Calculation

The combustion method is not stoichiometric and as an empirical factor must be determined using standard steels of known composition, similar in type and sulphur content to the samples being analysed (Note 4). The sulphur content of the sample is thereby obtained as a simple ratio between the volumes of alkali used in the titration of a standard steel and the samples. Theoretically, 1 ml. of $N/200$ sodium borate $\equiv$ 0·08 mg. of sulphur.

Notes

(1) The temperature range specified refers to the observed temperature inside the hot zone of the combustion tube, with 2½ l. of oxygen per minute passing through the system. It does not take account of local variations in temperature which occur during an actual determination.

A slightly lower temperature (*e.g.*, 1270–1300° C.) may be adequate for carbon and low-alloy steels. Temperatures up to 1350° C. may be required for heat-resisting and other very highly alloyed materials.

(2) Sample weights should be adjusted as follows:

1·0 g. for sulphur contents less than 0·15%
0·5 g. for sulphur contents of 0·15–0·30%
0·2 g. for sulphur contents of 0·30–0·75%.

In all cases where less than 1 g. is used it is recommended that the charge be made up to 1 g. with iron of known low-sulphur content.

Fine even millings or drillings are necessary. Millings are preferred to drillings. Coarse millings or turnings and light-curly coarse drillings are unsuitable and should be rejected. Some types of drillings can be made suitable by crushing or flattening in a percussion mortar.

In all cases the weighed charge should be intimately packed in the combustion thimble. For high-chromium rustless and heat-resisting steels and alloys, mix the sample with 1 g. of tin powder. For high-carbon ferrochromium, mix the sample with 0·5 g. of tin and 0·5 g. of ingot iron of known low-sulphur content.

Replicate results calculated on a 1-g. sample should lie within $\pm$ 0·0025% of sulphur for simple steels and $\pm$ 0·005% of sulphur for complex steels.

(3) The preheating period at full temperature before admitting the oxygen supply promotes a quiet even combustion and reduces the amount of iron oxide dust carried over in the gas stream. The period specified is sufficient for most steels, but very high-carbon steels, pig irons, and cast irons should be preheated for 4–7 min. With maximum preheating times, pig irons may be burned in sequence with little or no accumulation of iron oxide in the cool parts of the system.

Iron oxide should be removed from the tube with a stiff wire brush at the start of each series of tests and at intervals thereafter as necessary. The glass adapter, safety bulb, and distributor should be cleaned by immersion in boiling hydrochloric acid (1 : 1), rinsed, and dried between each series of tests.

(4) The sulphur content of standards is preferably determined by a reliable gravimetric procedure.

Determination of Silica in Blast-Furnace Slags

By the Methods of Analysis Committee

SYNOPSIS

The usual routine procedure for the determination of silica in blast-furnace slags includes two evaporations of the sample solution with excess hydrochloric acid. All the silica is not necessarily recovered by this treatment, and perchloric acid is shown to be a more rapid and effective reagent for dehydration of the total silica. Results are provided indicating that other possible reagents are less satisfactory, and a recommended method is described. 858

In view of certain difficulties encountered in the determination of silica in blast-furnace slags, it was considered that this procedure would be an appropriate subject for investigation by the Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories Analysis Sub-Committee of the B.I.S.R.A. Methods of Analysis Committee. A study group was accordingly appointed in the middle of 1947 to investigate the various aspects of methods applicable to this determination and to formulate a tentative standard method for examination by the Sub-Committee.*

PRELIMINARY INVESTIGATION

A bibliography on the determination of silica in oxide-bearing materials covering the most important work published up to the end of 1947 was prepared,[1, 2] and it was apparent that most methods for the determination of silica in blast-furnace slags depended upon the dehydration of chloride solutions of the sample, the dried and baked residue being redissolved in dilute hydrochloric acid. Data regarding the strength of acid for taking up the baked residue or the time required for digestion of the solution before filtration were inconsistent, however, and a series of experiments was carried out on pure sodium silicate solutions and on blast-furnace slags. Results on sodium silicate solutions showed that two dehydrations (with intervening filtrations and extractions of the baked residue by heating with 50 ml. of hot dilute hydrochloric acid (1 : 9) for 10 min. on the steam bath) gave a satisfactory recovery of silica. Furthermore, the presence of considerable amounts of iron had no effect on the results.

HYDROCHLORIC ACID DEHYDRATION

The first trials on 1·0-g. and 0·5-g. samples of blast-furnace slags, using hydrochloric acid as the dehydrating agent after a carbonate fusion, gave results varying by $\pm$ 0·2% of silica. The change in sample weight had no effect.

For acid-soluble slags decomposition with hydrochloric acid was satisfactory without being preceded by the more generally applicable sodium carbonate fusion. Extraction of the dehydrated residue could be achieved equally well by treatment with hydrochloric acid (sp. gr. 1·16) followed by boiling water, or by digestion for a short time with hydrochloric acid (1 : 9). It was later shown, however, that a very slight increase in the solubility of the dehydrated silica resulted from the latter treatment.

To recover the trace of silica remaining in the filtrate, three procedures were examined:

(i) A second dehydration with hydrochloric acid

(ii) Precipitation of the silica with iron and other hydroxides by adding ammonium hydroxide, separating the precipitate by filtration, dissolving it in hydrochloric acid, and dehydrating the silica with perchloric acid

(iii) Fuming the filtrate with perchloric acid.

From results obtained on synthetic solutions and on samples of blast-furnace slag, there was little to choose between the two latter procedures, but both gave more consistent recoveries than two dehydrations using hydrochloric acid.

In the course of this investigation it was found that noticeable losses of platinum occurred during carbonate fusions; research on this problem has been conducted and will be reported elsewhere.

OTHER REAGENTS FOR SEPARATION AND DEHYDRATION OF SILICA

Sulphuric acid, although a satisfactory dehydrating agent for silicic acid, was not considered, since the presence of major contents of calcium in blast-furnace slags would cause difficulties in operation, owing to the formation of large amounts of relatively insoluble calcium sulphate.

* The constitution of the Sub-Committee to 31.12.52 was Mr. G. E. SPEIGHT (*Chairman*), United Steel Companies, Ltd.; Mr. B. BAGSHAWE, Brown-Firth Research Laboratories; Mr. E. W. HARPHAM and Mr. I. HERBERT (to 31.3.52), Richard Thomas and Baldwins Ltd.; Mr. W. H. HESSON, Appleby-Frodingham Steel Co.; Mr. A. P. LUNT, Park Gate Iron and Steel Co., Ltd.; Mr. D. MANTERFIELD, Steel, Peech and Tozer; Mr. R. PRITCHARD (left 31.3.50, rejoined 1.4.52), Shelton Iron, Steel and Coal Co., Ltd.; Mr. N. D. RIDSDALE, Bureau of Analysed Samples Ltd.; Mr. C. W. SHORT, John Lysaght Ltd.; Mr. J. L. WEST, Hadfields Ltd.; Mr. T. H. WILLIAMS (from 1.4.50), Stewarts and Lloyds Ltd.; Mr. E. C. V. WISKAR, Dorman Long and Co., Ltd.; and Mr. J. O. LAY (*Secretary*), B.I.S.R.A. Mr. Harpham, Mr. Hesson, and Mr. Wiskar, together with Mr. G. Padget, representing the Chairman, formed the study group.

Paper MG/D/113/53 of the Methods of Analysis Committee of the Metallurgy Division of the British Iron and Steel Research Association, received 15th July, 1953.

Table I

RESULTS OF VARIOUS PROCEDURES FOR SILICA RECOVERY

a. Gelatine and Perchloric Acid

Analyst	Silica, %			
	MGS/39			MGS/40
	Gelatine	Perchloric	Total	Gelatine
1	29·9 30·1	1·0 0·7	30·9 30·8	32·25
2	30·5 29·05	0·35 1·7	30·85 30·75	31·3
3	30·7	...	...	31·8
4	30·7	...	...	31·25

b. Nitric Acid

Analyst	Sample MGS/39: Silica, %		
	1st Dehydration	2nd Dehydration	Total
1	25·0	4·45	29·45
2	29·65	0·25	29·9
3	28·85	1·0	29·85
4	24·4	3·7	28·1

c. Acetic Anhydride

Analyst	Sample MGS/39: Silica, %	
	As Scott and Furman*	Using Double Quantity of Acetic Anhydride
1	25·5	25·3, 23·45, 27·05

* W. W. Scott and N. H. Furman, "Standard Methods of Chemical Analysis," 5th ed., vol. 1, p. 816: 1939, New York, D. Van Nostrand Company.

Several investigators have pointed out the advantages of using gelatine or glue to assist precipitation of silica sols. Tests have been carried out to investigate whether precipitation of the silicic acid is more complete than by the usual dehydration procedures. The results obtained were not completely satisfactory, although several minor modifications were also examined. Sufficient has been done, however, to indicate that with further development the gelatine procedure may well form the basis of a useful method for silica, particularly for routine application, but at present it cannot be recommended as a standard procedure.

Acetic anhydride, although a powerful dehydrating agent under some conditions, was found to be quite unsuitable as a dehydrating agent for silicic acid. Very low and variable recoveries of silica were obtained under the various conditions of use.

Similarly, the dehydration of silicic acid in nitric-acid/nitrate solutions was unsatisfactory when operated under similar conditions to those used with the hydrochloric-acid/chloride solutions, and this technique was not further considered. Results of some of these experiments are recorded in Table I.

PERCHLORIC ACID DEHYDRATION

Having been used successfully as a dehydrating agent in the second stage of the hydrochloric acid method and having been adopted in the standard method for silicon in steel,[3] perchloric acid was next tried as a direct dehydrating agent for silica in slag.

A single dehydration with perchloric acid, in the absence of sodium salts, gave better recovery than a single dehydration with hydrochloric acid, although a trace of silica still escaped into the filtrate (*see* Table II). In the presence of sodium salts similar results were obtained with either reagent.

A tentative method for the determination of silica in blast-furnace slags was therefore prepared and tested. While it was realized that many blast-furnace slags would be completely soluble, or very nearly so, in mineral acids, the adoption of alkali fusion in the recommended method was considered to be advisable to ensure its general applicability. In this method,

Table II

COMPARISON OF HYDROCHLORIC AND PERCHLORIC ACID DEHYDRATION

Analyst	Sample MGS/169: Silica, %				Sample MGS/170: Silica, %			
	A	B	C	D	A	B	C	D
1	30·2	31·0	31·0	31·05	29·5	30·3	30·1	30·2
2	30·6	31·1	30·85	31·05	30·0	30·3	30·05	30·25
3	30·45	31·0	30·8	30·9	29·8	30·25	30·2	30·3
4	30·05	31·0	...	...	29·3	30·3	...	...
5	30·5	31·0	31·0	31·05	30·1	30·45	30·3	30·45
6	29·55	30·85	31·0	...	28·45	30·4	30·3	30·35
7	30·4	30·95	30·9	31·0	29·7	30·25	30·1	30·15
8	30·45	30·9	30·9	31·0	29·45	30·1	30·1	30·2
9	30·2	31·1	31·0	31·2	29·5	30·4	30·4	30·5
Av.	...	31·0	30·95	31·05	...	30·3	30·2	30·3

A = Single hydrochloric-acid dehydration
B = Hydrochloric-acid dehydration followed by perchloric acid
C = Single perchloric-acid dehydration
D = Double perchloric-acid dehydration

Table III

RESULTS BY THE RECOMMENDED METHOD

Analyst	Sample MGS/39: Silica, %		Sample MGS/40: Silica, %	
	A	B	A	B
1	30·75	...	32·8	...
2	30·7	30·45	32·6	32·4
3	30·7	30·5	32·65	32·7
4	30·7	...	32·55	...
5	30·85	30·85	32·85	32·45
6	30·95	30·6	32·8	32·65
7	30·75	30·5	32·7	32·7
Av.	30·75	30·6	32·7	32·6
Range	0·25	0·4	0·3	0·3

A = Recommended method, B = Single perchloric-acid dehydration

dehydration is carried out by fuming with perchloric acid, residual silica being recovered by repeating the operation. The final solution from the perchloric-acid dehydration constitutes a suitable solution in which to determine iron, aluminium, titanium, etc., in the usual scheme of silicate analysis.

Typical results obtained by the recommended procedure described in the Appendix are given in Table III.

CONCLUSIONS

Although of some value as a routine procedure, the familiar hydrochloric-acid dehydration method for the determination of silica in slag has the disadvantage that a large and irregular proportion of the total silica passes into the filtrate after the first dehydration process, so that the resulting solution requires further treatment for the recovery of this silica; some silica may even be left behind in the second filtrate. A single perchloric-acid dehydration provides more rapidly a result adequate for routine operation, and a second dehydration under the same conditions gives complete recovery.

APPENDIX

Recommended Method

Solutions Required

Hydrochloric Acid (1 : 4)
Sulphuric Acid (1 : 1)

Procedure

Transfer 4 g. of anhydrous sodium carbonate and 1 g. of the sample (Note 1) to a platinum crucible, mix thoroughly, and close the crucible with a platinum lid. Heat at about 450° C. for 10 min. and at 1000° C. for a further 15 min.

Cool, transfer to a 600-ml. squat resistance-glass beaker containing 60 ml. of perchloric acid (sp.gr. 1·54), warm until the melt has dissolved, rinse and remove the crucible and lid. Add 2–3 ml. of nitric acid (sp.gr. 1·42), cover with a watch-glass, evaporate the solution to fumes of perchloric acid and continue fuming for 10 min. at such a temperature as will maintain a steady reflux of acid on the walls of the beaker (Note 2).

Cool, add 20 ml. of hydrochloric acid (sp.gr. 1·16), cover the beaker, and heat to boiling. Add 100 ml. of cold water and filter the solution immediately through a paper pulp pad, rinsing with hot hydrochloric acid (1 : 4) and removing silica with a 'policeman.' Wash thoroughly with hot hydrochloric acid (1 : 4) and cold water alternately and transfer to a platinum crucible (Note 3).

Evaporate the filtrate and washings to fumes and repeat the separation, combining the residue with that already obtained.

Ignite the combined residue below 500° C. until carbonaceous matter is entirely removed, then at 1050–1100° C. to constant weight, cool for 10 min. in a desiccator, and weigh (*A*) (Note 4).

Moisten the residue with water, and add two drops of dilute sulphuric acid (1 : 1) and 5 ml. of hydrofluoric acid. Evaporate to dryness, heat gently to the expulsion of sulphur trioxide, and finally ignite at 1050–1100° C. for 10 min., cool as before, and weigh (*B*). The difference in weight ($A - B$) represents the silica content of the sample taken (Note 5).

A blank assessment should be made under identical conditions and the necessary correction made.

Notes

(1) Samples difficult to decompose may need careful grinding to pass B.S. Sieve No. 100, but coarser material is often satisfactory. For slags containing over 35% of silica, 0·5 g. of sample should be taken.

(2) Although sodium carbonate fusion is preferred for referee analyses, many blast-furnace slags can be decomposed by hydrochloric acid, using the following procedure:

> Digest 1 g. of sample, moistened with water, with 30 ml. of hydrochloric acid (sp.gr. 1·16). Add 2–3 ml. of nitric acid (sp.gr. 1·42) and 60 ml. of perchloric acid (sp.gr. 1·54), evaporate to fumes, and treat as above.

(3) Completion of the determination at this stage produces results about 0·2% (2 mg.) of silica below the true content.

(4) The weighing of silica residues should be carried out as rapidly as possible, as silica is slightly hygroscopic, even when dehydrated at 1050–1100° C.

(5) Replicate results should agree within ± 0·15% of silica.

References

1. B.I.S.R.A. : Private communication.
2. E. W. HARPHAM : "Bibliography on the Determination of Silica in Oxide-Bearing Materials," B.I.S.R.A. Report MG/DA/105/49.
3. British Standard 1121, "Methods for the Analysis of Iron and Steel. Part 10: Silicon in all types of iron and plain and alloy steels," 1948.

CORRESPONDENCE

Correspondence on the Paper—

"The Protection of Iron and Steel by Metallic and Non-Metallic Coatings—II," *by J. C. Hudson and J. F. Stanners**

Dr. **T. P. Hoar** (Department of Metallurgy, University of Cambridge) wrote: There is one matter in this otherwise excellent paper where I think the authors give a wrong impression. In Tables II and II*a* certain results for aluminium coatings sprayed by the powder pistol are given, from which it may be inferred that such coatings are very much inferior to other aluminium coatings. Elsewhere (p. 386) the authors say that these results are 'open to doubt.' This is surely an understatement. The coatings referred to were incorrectly made—not by, and through no fault of, the authors—from powder containing over 3% of copper, and consequently the results, as an assessment of properly produced powder-sprayed aluminium coatings, are valueless. When Hudson and Banfield published preliminary results on these coatings in 1946 they made a similar over-slight disclaimer of them, insufficient to prevent the misapprehension arising that powder-sprayed aluminium coatings are necessarily inferior to other aluminium coatings; it is a pity that these invalid tests are again recorded, and given tabular status modified only as 'open to doubt.' The present authors mention, indeed, that the experiments with powder-sprayed aluminium coatings have been repeated, with tests started in 1950: in view of the misapprehension to which the earlier paper gave rise, it would have been satisfactory if preliminary 3-year results of these tests with properly made powder-sprayed aluminium coatings had been indicated in the present paper. Could the authors now tell us how the powder-sprayed aluminium coatings in the 1950 series are, so far, behaving compared with other aluminium coatings?

In an extensive series of tests begun in 1951 to examine the behaviour of mixed and alloyed powder-sprayed coatings, in comparison with those of zinc and aluminium, we have so far (2 years) found that specimens carrying 3-mil powder-sprayed aluminium and zinc coatings, used as controls, are showing no rust at Cambridge, Greenford, Stratford (London)—a highly industrial atmosphere—and Frinton-on-Sea (Essex). Some of our similar aluminium-sprayed specimens at Kure Beach showed very slight rust staining in the earliest stages; this has since considerably diminished, as has often been noted for aluminium-sprayed steel.

AUTHORS' REPLY

Dr. **J. C. Hudson** and Dr. **J. F. Stanners** wrote in reply: We fully agree with Dr. Hoar that the behaviour of our first series of sprayed aluminium coatings, as produced by the powder pistol in 1940, may not be typical of the same type of coating as that produced nowadays. Unfortunately, the experimental fact that a good sprayed aluminium coating has a life of more than 11 years in our tests at Sheffield renders it possible that any statement of the results obtained so far with the 1950 specimens might prove misleading. It follows that Dr. Hoar's point can only be satisfactorily settled after several more years' exposure. With this reservation, we may remark that *after about* 3 *years' exposure* no difference was detectable between sprayed aluminium coatings of present-day commercial purity applied by different processes; moreover, it was evident that the presence of copper in the coatings had a generally detrimental effect on their protective value.

* *J. Iron Steel Inst.*, 1953, vol. 175, pp. 381–390.

Correspondence on the Papers—

"Temper-Brittleness: A Critical Review of the Literature," *by B. C. Woodfine**

"Some Aspects of Temper-Brittleness," *by B. C. Woodfine*†

"Temper-Brittleness in High-Purity Iron-Base Alloys," *by A. Preece and R. D. Carter*‡

"Effect of Arsenic and Antimony on Temper-Brittleness," *by G. W. Austin, A. R. Entwisle, and G. C. Smith*§

Dr. **L. D. Jaffe** (Watertown Arsenal, U.S.A.) wrote: Dr. Woodfine's two papers appear to constitute a most valuable addition to the literature on temper-brittleness. Some question may, however, be raised about a few of his conclusions.

He states as established that "temper-brittleness does not occur in plain carbon steels with less than 0·6% of Mn." Brittleness on tempering occurs in plain carbon steels, as the author admits; he defines temper-brittleness as excluding such brittleness. The quoted statement is therefore a definition rather than a conclusion; others[1] have chosen other definitions.

The conclusion that a grain-boundary etch can be produced in temper-brittle steels by aqueous picric acid confirms work[2] which may have been overlooked.

The author concludes that brittle fracture occurs in tempered specimens by cleavage and in temper-embrittled specimens along grain boundaries. This conclusion should apparently be qualified; the data in the paper controvert such an absolute distinction.

Dr. Woodfine concludes that temper-brittleness at 550° and 575° C. decreased as tempering time increased. This conclusion is based upon a correction for hardness change of − 8° C. per 27 D.P.N. This figure was obtained by tempering for 1 hr. and for 5 hr. at 650° C.; if the data for 50 hr. at 650° C. are considered, the correction would be + 7° C. per 57 D.P.N. A hardness correction cannot be established on the basis of tempers for various times at 650° C., at which temperature significant embrittlement occurs simultaneously with softening.

In the same way, the author's conclusion that prolonged tempering at 650° C. reduced subsequent embrittlement reflects the finding that the presence of embrittlement reduces the transition-temperature increase in subsequent embrittlement treatments.[3]

In the paper by Professor Preece and Dr. Carter, it is a little difficult to understand the basis of the authors' conclusion that molybdenum decreases the equilibrium extent of embrittlement, rather than the rate at which

* *J. Iron Steel Inst.*, 1953, vol. 173, Mar., pp. 229–240.
† *Ibid.*, 1953, vol. 173, Mar., pp. 240–255.
‡ *Ibid.*, 1953, vol. 173, Apr., pp. 387–398.
§ *Ibid.*, 1953, vol. 173, Apr., pp. 376–386.

equilibrium is attained. They measured the extent of embrittlement of the molybdenum-bearing steels after 670 hr. embrittlement only; how does this throw any light on the rate or equilibrium extent of embrittlement?

Finally, in regard to the paper by Professor Austin and his co-workers, it would normally be expected that the transition temperature of a steel would decrease as its hardness fell. The authors' failure to find such a decrease on prolonged holding at 620° C. apparently reflects temper-embrittlement taking place simultaneously with the softening. The reported decrease in susceptibility to temper-brittleness after such prolonged holding is therefore probably an example of the effect of prior temper-embrittlement in reducing the transition-temperature increase produced by a subsequent embrittlement treatment.[3]

AUTHORS' REPLIES

Dr. **B. C. Woodfine** (B.I.S.R.A.) wrote: I should like to thank Dr. Jaffe for drawing my attention to the work of Lamborn. The first point, concerning the 'temper-embrittlement' of plain carbon steels, involves the problem of nomenclature. In the papers under discussion the term 'temper-brittleness' was used to denote the intergranular embrittlement produced in certain low-alloy steels in the temperature range 625–350° C., and the conditions of heat-treatment were designed as far as possible to avoid changes in transition temperature due to other causes such as ferrite grain growth. This restricted use of the term 'temper-brittleness' has the advantages both of clarity and of preserving historical continuity. The definition suggested by Libsch, Powers, and Bhat[1] (which presumably receives some support from Dr. Jaffe) that any embrittlement occurring on tempering, no matter what its origin, should be called 'temper-brittleness,' is considered to be a retrograde step. This definition includes several widely different forms of embrittlement under one heading, and even the division into 'reversible' and 'irreversible' embrittlement does not succeed in providing a clear system of nomenclature. It would seem infinitely preferable, for example, to make a clear distinction between the embrittlement which occurs in plain carbon steels as a result of ferrite grain growth and the intergranular embrittlement which takes place (under different conditions) in low-alloy steels in the range 625–350° C.

It was unfortunate that the conclusion concerning the nature of the brittle fracture observed in tempered and temper-brittle specimens implied that each failed exclusively with one type of fracture. The intention was to stress that the controlling factor in one case was the cleavage strength and in the other the intergranular strength. In the fine-grained tempered steels occasional areas of ductile fracture were found linking cleavage facets, but there was no indication of intergranular fracture. The occurrence of intergranular fracture in quenched and tempered coarse-grained alloy steels has been noted previously and, whilst it may be connected with the changes produced by overheating, it is clearly an abnormal phenomenon in regard to temper-brittleness. Although the embrittlement in temper-brittle steels is the result of a lowering of the cohesion across what were the austenite grain boundaries with the consequent appearance of intergranular fracture, this does not preclude the presence of cleavage fracture in areas where either the grain-boundary cohesion was still high or the orientation of the grain relative to the direction of propagation of the crack was more favourable for cleavage than intergranular failure.

In questioning the validity of the hardness correction applied to the specimens tempered at 550° and 575° C., Dr. Jaffe appears to have overlooked the fact that a correction of either − 8° C. per 27 D.P.N. or + 7° C. per D.P.N. leads to exactly the same conclusion, *i.e.*, that temper-embrittlement decreases with prolonged holding at 550° or 575° C. The first of the hardness corrections (the one actually used) implies that only part of the observed fall in transition temperature can be accounted for by softening, and the second (suggested by Dr. Jaffe) indicates that if the transition temperature increases with decreasing hardness a very much greater decrease in temper-embrittlement is actually occurring. The hardness correction of − 8° C. per 27 D.P.N. obtained from 1-hr. and 5-hr. tempers at 650° C. was used in the paper because the hardness after 5 hr. at 650° C. was almost the same as that after 128 hr. at 575° C. Although Dr. Jaffe does not consider that a valid hardness correction can be established by tempering for different times at 650° C., recently published work[4] by himself and his colleagues not only made use of a hardness correction established by tempering for 1 hr. at different temperatures but also extrapolated this correction to higher temperatures, where its validity had not been established. Dr. Jaffe states that at 650° C. "significant embrittlement occurs simultaneously with the softening," but offers no evidence for this, nor does he indicate what type of 'embrittlement' he has in mind. The results presented in the paper for steel *K* show that after 1, 5, and 50 hr., at 850° C. the hardness values were 280, 253, and 223 D.P.N., respectively, whilst the specimens had transition temperatures of − 59°, − 67°, and − 52° C., respectively. The brittle fractures of all specimens tempered at 650° C. occurred by cleavage. These results indicate that with tempering at 650° C. the transition temperature first decreases and then increases as the hardness falls, which can readily be explained on the basis of the normal structural changes occurring in a low-alloy steel on tempering. This has recently been done[5] for some results obtained by Dr. Jaffe and his co-workers.

To explain the decrease in temper-embrittlement observed after prolonged tempering at 650° C., Dr. Jaffe again states that embrittlement has occurred at 650° C. Even if we assume this to be so (noting, however, that the maximum increase in transition temperature at 650° C. is only 15° C. between 5 and 50 hr.), the results given in Table II of the paper would appear to show that the subsequent embrittlement at 500° C. should not be affected by this previous embrittlement. The results for the double embrittling treatments at 550° and 500° C. demonstrate that the embrittlement in the second treatment is the same as would have occurred if the first treatment had not been given. The disagreement between this conclusion and that reached by Dr. Jaffe must in some way be connected with the fact that his specimens were subjected to treatments involving slow cooling plus isothermal holding, whilst the results in Table II are for two isothermal treatments. The conclusions concerning the effect of prolonged heating at 650° C. are ,however, based on two isothermal treatments. Even Dr. Jaffe's results do not indicate such a great effect of previous embrittlement on subsequent embrittlement as would be shown by steel *K*, where the increase in transition temperature between 1 and 50 hr. at 650° C. is only 7° C., whilst the decrease in embrittlement shown by the temper-brittle specimens is 88° C. The diffusion of alloying elements from ferrite to carbide which takes place on tempering would appear to provide a satisfactory explanation of the reduction in the temper-embrittlement after prolonged tempering at 650° C.

Professor **A. Preece** (King's College, Newcastle-upon-Tyne) wrote: Dr. Jaffe has drawn our attention to an unfortunate omission from the paper. Embrittlement tests on the molybdenum-containing alloys were in fact

carried out at 500° C. for several different times, the longest of which was 670 hr. In preparing the paper for publication, results for all but the longest treatment were omitted, although the conclusion drawn from them was left. The full results, which show a definite levelling-off of transition temperatures at times approaching 670 hr., were:

Time at 500° C., hr.	Alloy 42 (Fe–Mn–P–C–Mo) Hardness, D.P.N.	Alloy 42 (Fe–Mn–P–C–Mo) Transition Temp., ° C.	Alloy 64 (Fe–Cr–P–C–Mo) Hardness, D.P.N.	Alloy 64 (Fe–Cr–P–C–Mo) Transition Temp., ° C.
0	243	−121	241	−137
2	250	−112	...	...
10	247	−113	...	...
48	251	− 97	234	−132
168	244	− 89	240	−127
670	252	− 95	240	−125

Professor **G. Wesley Austin** (Cambridge University) wrote: The reason for only a small change in the value of the unembrittled transition temperature in the experiments to which Dr. Jaffe refers is not clear, and more information is required upon the general effect of hardness level on transition temperature. However, Dr. Jaffe's explanation would appear to be incorrect, in view of the fact that although the 'tough' specimens after tempering at 620° C. did show some intergranular fracture (*i.e.*, they were to a small extent embrittled), the amount of this intergranular fracture fell off with tempering time. This small amount of embrittlement probably occurs during the heating of the specimens to 620° C. After 32 hr. tempering at 620° C. the brittle fractures in liquid air were entirely due to cleavage, so that prolonged holding at this temperature would appear to result in no appreciable amount of temper-embrittlement.

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1. J. F. Libsch, A. E. Powers, and G. Bhat: *Trans. Amer. Soc. Metals*, 1952, vol. 44, p. 1058.
2. I. R. Lamborn: *Australasian Eng.*, 1948, 8th Nov., pp. 39–41; *Steel Processing*, 1949, vol. 35, pp. 86–89.
3. L. D. Jaffe, D. C. Buffum, and F. L. Carr: *Trans. Amer. Soc. Metals*, 1953, vol. 45, pp. 725–731.
4. F. L. Carr, M. Goldman, L. D. Jaffe, and D. C. Buffum: *Trans. Amer. Inst. Min. Met. Eng.*, 1953, vol. 197, p. 998; *J. Met.*, 1953, vol. 5, Aug.
5. B. C. Woodfine: To be published.

Letter to the Editor

THE CORROSION POTENTIAL OF STAINLESS STEELS DURING STRESS CORROSION

We have measured the electrode potentials of several stainless steels under stress-corrosion conditions. Wire specimens (0·02 in. dia.) in longitudinal tension were exposed to boiling aqueous magnesium chloride solution (42% $MgCl_2$, 154° C.). Figure 1 shows typical potential/time curves for an 18/10/3/1 Cr–Ni–Mo–Ti steel: similar results have been obtained with other compositions.

Unstressed specimens give results generally similar to those given by tin[1] and iron[2] in dilute salt solutions; the curves may reasonably be explained by similar stages in the development of corrosion:

(i) The solution penetrates into pores in the surface oxide film with anodic solution of the metal at its base; the corrosion potential falls as the film cathode becomes polarized by the corrosion current

(ii) Hydroxide is precipitated within the pores giving film repair, so that the potential rises; the hydrogen-ion concentration within the pores concomitantly increases

(iii) When the acidity within the pores becomes high enough, the metal begins to dissolve to soluble products, hydroxide dissolves, and the film is undermined. Substantial pitting starts, and the corrosion potential falls.

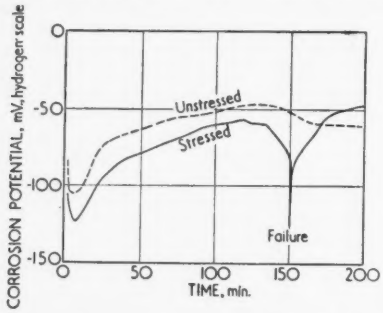

Fig. 1—Typical potential/time curves for an 18/10/3/1 Cr–Ni–Mo–Ti steel, bright-annealed: unstressed, and stressed to two-thirds of its 0·1% proof stress, in 42% $MgCl_2$ aq. at 154° C.

Moderately stressed specimens behave similarly until the potential maximum is reached, except that the potential is 10–20 mV. less noble than that of an unstressed specimen. The potential then falls rapidly for a few minutes until breakage of the wire by stress-corrosion cracking occurs (Fig. 1); it then recovers, doubtless through film-repair of the now unstressed fractured surfaces of the broken wire. Mechanical tensile tests on specimens removed before complete breakage show that the cracking begins only at the start of the rapid potential fall. Confirming this, extensometer measurements made during the stress-corrosion tests show that no extension occurs until the start of the rapid potential fall. Thus the major part of the life of a moderately stressed specimen under the present, and probably under other, conditions of stress corrosion is the development of breakdown conditions in the surface film; and measurements and comparisons of time to failure of such specimens give information mainly of the development of film-breakdown and crack-initiation conditions, rather than of the rate of the cracking process proper.

More highly stressed specimens have a somewhat shorter total time to failure. Potential measurements show that the increased stress somewhat reduces the time needed for the development of film-breakdown conditions, but has little or no influence on the rate of the cracking process once it has started.

On specimens exposed to low applied stress, the cracking process does not begin until a long time after film-breakdown conditions have been established; evidently a relatively extensive corrosion pit is needed to initiate the cracking process under low applied stress.

Full details of the work will be reported later.

T. P. Hoar
J. G. Hines

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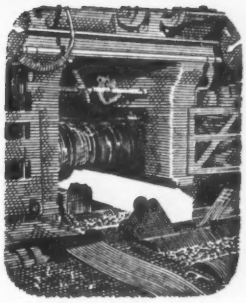
1. T. P. Hoar: *Trans. Faraday Soc.*, 1937, vol. 33, p. 1152.
2. T. P. Hoar: *Ibid.*, 1949, vol 45, p. 683.

IRON AND STEELWORKS ENGINEERING



THE IRON AND STEEL ENGINEERS GROUP

THE IRON AND STEEL ENGINEERS GROUP

REPORT OF THE TWENTY-THIRD MEETING

THE TWENTY-THIRD MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at the Offices of the Institute, 4, Grosvenor Gardens, London, S.W.1, on Wednesday, 28th October, 1953. Mr. C. H. T. WILLIAMS (The Park Gate Iron and Steel Co., Ltd.), Chairman of the Group, presided.

The MORNING SESSION was devoted to the presentation and discussion of a paper entitled "Roll-Design Research as Applied to Rolling-Mill Development," by Mr. B. Robinson and Mr. W. A. Lugar (The Park Gate Iron and Steel Co., Ltd.).

The discussion of this paper will appear in the July issue of the *Journal*.

The AFTERNOON SESSION was occupied by the presentation and discussion of a paper by Mr. W. Bailey (Davy and United Engineering Co., Ltd.), entitled "Manipulating Equipment, Guides, Guards, and Strippers for Rolling Mills."

PROCEEDINGS OF THE AFTERNOON SESSION: 2 P.M. to 4 P.M.

Discussion on the Paper—

MANIPULATING EQUIPMENT, GUIDES, GUARDS, AND STRIPPERS FOR ROLLING MILLS*

Mr. **W. Bailey,** in presenting his paper, said that because of pressure of work he had by no means covered the subject adequately, but having had second thoughts he would like to mention other equipment used for manipulation.

Various types of ingot cars were illustrated by slides, and the author stressed that the delivering of heavy ingots, which necessitated massive ingot cars, presented a number of problems to the designers. With speeds of up to 1000 ft./min. it is extremely difficult to check the cars when tilting at the roller table, as the normal limit switches are not sufficiently robust.

Other problems arose owing to the heavy wheel loads and drive transmission.

The author stressed that the mills in the U.K. and in Europe generally presented difficult problems as compared with those in America, as the smaller outputs over here demanded greater flexibility in order to cover the wider range of products from the mill. Slides of various manipulators to cover this requirement were shown. Slides were also shown illustrating slab and crop handling at the shears.

Attention was drawn to the diagrams in the paper illustrating double drafting on 3-high mills when rolling joists. The author stated that in this country the 2-high reversing mill seemed to find more favour than was deserved in his opinion; manipulation was easier with the 2-high mills, but he suggested that this could form a subject for discussion.

With the 2-high set-up as is common in the U.K. in the cross-country mill, he considered that there should be electric screw-down on the roughing with preferably both electric and hand screw-down on the second roughing and hand screwing on the finishing stand. This arrangement had been applied on one or two recent mills.

A slide was also shown of plates entering gear and a plate turn-table for broad-siding the slabs, but the author suggested that the method of turning slabs which he described in his paper was better.

Mr. **W. French** (Darlington and Simpson Rolling Mills Ltd.): In Fig. 11 there are some side guards which are shown with a little screw in the foot of them. That is not a very satisfactory way of fastening a side guard, and it can only be used for very plain equipment.

On p. 206 the author refers to guides and strippers of hard cast iron which need to be dressed to shape. Many people would object to having to do this, as the benefit of the skin hardness of the metal and some of the wearing qualities of the guide are thereby lost. If the quantity of guides warrants it, non-ferrous patterns are desirable because they usually provide benefits very much greater than those of the old wooden pattern.

I agree that it is an advantage to mount the rolls, the guides, and the tackle in a changing bed away from the mill if that is possible, because I am certain that over a period of time changing crews can be so trained

* *J. Iron Steel Inst.*, 1953, vol. 175, pp. 198–213.

as practically to eliminate the additional tackle requirements or tackle adjustments when the roll stands are put in the mill.

The author says that repeaters are fairly commonly used in breaking down and finishing stands, and then states that heavy bars can be repeated with comparatively short radii. Would he elaborate on this point and inform us what is the short radius which he has in mind, or what it might be in relation to the size of the bar being lifted?

In Fig. 12, what percentage of the length of the bar is supported by the automatic guide as the bar comes out, to ensure that the bar turns at right angles when it falls down for the next pass?

In Fig. 13, dealing with guides and stripper tackle for the 2-high and 3-high mills, it appears that the side guards are fastened through bolts by cramps underneath the bottom of the rest bar. This is not ideal; a much more satisfactory arrangement can be achieved by using the spigoted cramp and T-headed bolts for locating purposes.

Figure 15 shows an admirable arrangement of a table cramp, which from a tackle point of view is very much superior to a cramp bar located in slots in the sides of housings. There is a great improvement if the height of the cramp is made adjustable by a screw wedge operated from the face of the cramp.

In Fig. 17 the delivery guide arrangements are not ideal, since the guides, being fixed on the cramps, cannot maintain too positive a contact on the rolls, and so the mill can only be used for rolling very plain material and stripping very plain sections. The wedge on the top of the gear could work loose by the friction of the bar outgoing through the guides.

Ideally, each section and each pass should have its own tackle, which should not be used for other sections, and which is not thrown on the floor and damaged. As a long-term policy such a scheme, while being elaborate and expensive, will pay dividends.

Roll designers should not be responsible for the tackle. My own view is that the system which we adopt is the best, *i.e.*, the roll designer makes his designs, and then the operating staff look at them and decide what tackle should be made, and it is then made in the engineering department.

The T-headed bolt in conjunction with the spigoted cramp is the best method of attachment of guides, since cotters and wedges are very outmoded and lead to difficulties.

Mr. **Bailey:** On the question of cost, we can save a considerable amount of expense and material, with comparable strength, by using welded heads, because they lend themselves readily to changes in design and make it possible to put the material in the right place.

There are a number of guides which have wedges as well as the bolts. In Fig. 15 something could be done as on strip mills, where there is a small jack, something like a car jack, which can be used instead of bothering with the packing underneath the cross-beam. The operators do not like 'gadgets' on a mill, and designers should avoid putting in elaborations, but if something simple and reliable can be employed to help the men it is all to the good.

On the question of standardization, in a drawing for a guide I saw in America the outer frame of the guide was the same for every stand; this made for considerable simplification. There are too many guides which are not standard. The question of guide storage is one which has never been taken seriously enough. In a mill guides are found all over the place, and sometimes I do not know how the right one is found.

In the design of guides the first thing to establish is the collar width, and until the engineer knows this he cannot design anything. That is why the roll designer and the engineer must work very closely together.

Many questions on repeaters, including Mr. French's query on the radius for repeating, are answered in a future paper by Norlindh.*

Mr. **J. A. Kilby** (Colvilles Ltd.): On the question of the universal manipulator and the one-sided arrangement as compared with the double-sided arrangement, the former is very tidy and leaves one side of the mill quite clear. It was originally used for reasons of space, but the alternative double-sided arrangement has a number of advantages. There is no mechanism between the roller tables to cause trouble at a later stage, and in general the whole construction of both manipulators and roller tables is less complicated. On p. 199, after stating that the beams are carried on rollers or slides in the roller-table distance pieces, the author says "provision is made to exclude scale from wearing faces" and again on p. 201 he says that scale can easily be kept out of bearings with modern seals. I strongly disagree with this statement. It is a most difficult problem to keep scale out of bearings, particularly on plate mills where high-pressure water is used and the scale is so fine that it acts as an abrasive and finds its way into both bearings and gears in spite of taking every precaution.

The value of the paper would have been enhanced had the author devoted some space to the handling of scrap. In plate production more than 30% of the ingot is converted into scrap of one form or another and the scrap usually takes more handling than does the prime product.

What is the maximum size of ingot for which the author would design the normal type of side-guard manipulator? Reference is made to ingots up to 25 tons. Is that the limit? The author showed a slide which indicated laying-down gear on a manipulator. Is the provision of such a device not desirable?

Is it wise to use welding so extensively in heavy mills, particularly for side guards? Admittedly a good deal of weight will be saved, but is there sufficient experience available to indicate that a welded side guard will stand up indefinitely to heat? Will there not ultimately be trouble with the mounting of the tilting elements?

What determines when pushers should be applied to plate mills? Is it the reduction required to be effected on the slab, or the relatively short length of the slab, which makes it necessary?

Mr. **Bailey:** I consider the one-sided manipulator to be the best and there is a new design out now. At present the off side and the drive side are on separate beams, but there is a new scheme to combine the two, one above the other. That will do away with one of the objections which has been raised, but there will still be the problem of scale. We have sliding floor plates, however; this keeps off a good deal of the scale, which, however, cannot be completely prevented from blowing in. The sliding type excludes the scale better, and causes less mechanical trouble, than the roller type. I cannot see any other objections, except the cross-beams. It is ideal to keep the open side free for roll changing; I should not like to be obliged to carry out roll changing with the drives on both sides. Probably it will be agreed that the modern tendency to put the drives on the floor rather than carry them on the heads is an advantage. I showed a slide with all the drives mounted on top, and that entails travelling cables, etc. We have tried to locate all the driving gear on a solid foundation; this can be done with double-sided drive, but I prefer single-sided myself.

* S. E. M. Norlindh, *J. Iron Steel Inst.*, 1954, vol. 176 pp. 391–405.

Scale on roller gear is admittedly a problem, but does not cause so much trouble with the latest design of tables. There is just as much trouble in keeping it out as in keeping the oil in, but it can be done by increasing the number of labyrinths. We now have double the number that we used to have, and we do not have much trouble.

In handling scrap in large quantities we like to put the scale pit right away from the mill with a crane on its own for scale grabbing, because in a number of the plants which I have seen there is the nuisance of waiting for a jib crane to be available. In regard to scrap on the bloom shears, most firms are content with the crop pit, accessible to the crane, although more elaborate systems are in operation. When considering the layout of plant it is very necessary to put the machines in the right place and not have a cramped arrangement which makes it difficult to get the scrap away. We have found a preference lately for a pit with water in it for shear scrap.

Although I have never seen an ingot weighing more than 25 tons, there should be no difficulty in dealing with 30 tons or more, but the value of the big ingot is debatable.

Laying-down gear on manipulators might save the roller gear taking a blow, although in the modern design the blow is taken by easing off the off-side head and letting it run back, to lower the big ingots which are handled without a laying-down gear.

There is no doubt about the value of welded side guards. There has been a little trouble through sagging, but that was due to lack of experience in design. We have had welded side guards working now for years without any trouble. Damaged portions can be easily repaired, and we have a satisfactory repair service scheme for manipulator heads.

With a slab pusher the bite angle at the mill can be increased, and short slabs can be dealt with. I do not know why people persist with narrow slabs. A 54 × 20-in. slab can be run lengthwise up the roller gear, but in the mill itself collared rollers or something similar are required, and to get it over a cramp bar is not easy. That is where the pusher can be of use.

Mr. **G. A. Phipps** (Guest Keen and Nettlefolds (South Wales) Ltd.): I agree with Mr. French's remarks on the use of the wedge on Fig. 15. It is invaluable, particularly on cobbles, saving us a lot of smashes.

The modern mill with bottom-roll adjustment does not require vertical adjustment. With bottom-roll adjustment the guide bar can practically remain a fixture, apart from occasional padding when rolls are reduced in diameter, if there is not sufficient movement in the wedge to take it up. To add anything which would, in the case of a cobble, probably be broken, is not worthwhile.

What means are there of setting up on the pass line the roller entry guides of Fig. 20, particularly if the mill is working 3-stand ? Why are three rollers used ? We find two rollers ample; a third is unnecessary and can probably lead to more difficulties. The first roller seems to be too far away from the mill. The angle given for the rollers is 110°. In our experience, 130° is far better, and gives a much longer roll life.

Mr. **Bailey:** When I spoke of vertical adjustment I had general purposes in mind. It may not be necessary with roll adjustment.

I cannot tell you much about the 3-roll guide except that when I saw it on a new mill I was impressed by it; whether it will work as well with two rollers I do not know. A great amount of water was used on the roller guides.

Dr. **W. S. Walker** (Round Oak Steelworks Ltd.): In steelworks-plant engineering it is essential to strike a balance between the price and weight of any job. This is particularly so in the case of rolling-mill equipment. Even though modern design methods are elucidating many of the complex stress problems it is still necessary to employ generous scantlings if we want a sound trouble-free job. This question of weight brings to the fore the use of weldments rather than castings in mill equipment, and I think that in the future there will be more and more weldments used in rolling-mill equipment.

The other point I should like to emphasize is the question of adjustment on side-guard manipulators in heavy mills so as to enable them to be aligned. Serious consideration should be given to this matter.

Mr. **Bailey:** Dr. Walker's alignment difficulty is an isolated and unusual case; it is not easy to make provision for alignment.

On the question of damping trouble and fatigue in castings and welded structures, we are not economising to the extent of making them light. There used to be a stock phrase in our specifications: " of rigid and robust construction "; and we have always used a high safety factor. We do not believe in being light, but we have to compromise, and, as I have said, in many cases a casting is given a certain thickness not for it to fulfil its purpose but because it has to have that thickness in order to be cast. The correct welding techniques are being applied, and we have welded manipulator heads which have been in service for years.

Dr. **Walker:** I should like to make it clear, with regard to the question of roll design and tackle, that I do not think they ought to be separated. Mr. French indicated two separate divisions. I suggest that it must be a co-operative effort.

Mr. **W. A. Lugar** (Park Gate Iron and Steel Co., Ltd.): In India, after I had dealt with the roll passes, a draughtsman would lay out on a full-size board the various diameters, the centre-line of the cramp bar, etc., and design the section of the guide accordingly. They were then cut out by oxy-acetylene burner, machined in a small machine shop, and fitted to the roll in a dummy housing with a dummy cramp. That it paid dividends is evidenced by the fact that an Indian roller on one 36-in. mill could roll 420 tons of 90-lb. flat-bottom rails in 7½ hr. without difficulty. To simplify matters we also made a separate cramp bar for each section, and it was as easy to change the cramp bar complete before taking the bottom roll out as to fit up the side guards.

The **Chairman:** That procedure was adopted 30 years ago at Park Gate. It was the first time that I had seen a roll designer's designs put out drawing-board size and being appreciated by the engineers.

Mr. **R. Stewartson** (United Steel Companies Ltd.): Three further manipulating devices which are operating satisfactorily are worth attention.

Figure *A* shows a device for turning billets as large as 8 in. square × 7–8 ft. long into box passes. Two manipulators are mounted one behind the other and the arms are operated by pneumatic cylinders. Initially the billet is run directly over one of the arms as shown in (i) and both arms are raised to support the billet at 45° as shown in (ii). The pressure on the right-hand cylinder is then reduced as in (iii) until the billet is turned over. The sequence of valve operations is controlled by an electric timing device.

Figure *B* shows a manipulator for a 32-in. 2-high mill, used to turn up ovals into round passes of 3–5-in. dia., and diamonds into square passes from 2½-in. upwards. The two gripping rollers are pneumatically operated and can be ambushed beneath the roller table. When in the gripping position, the framework on which they are mounted can be rotated through 90° or 45° to bring the bar into the correct position for entering the pass. The

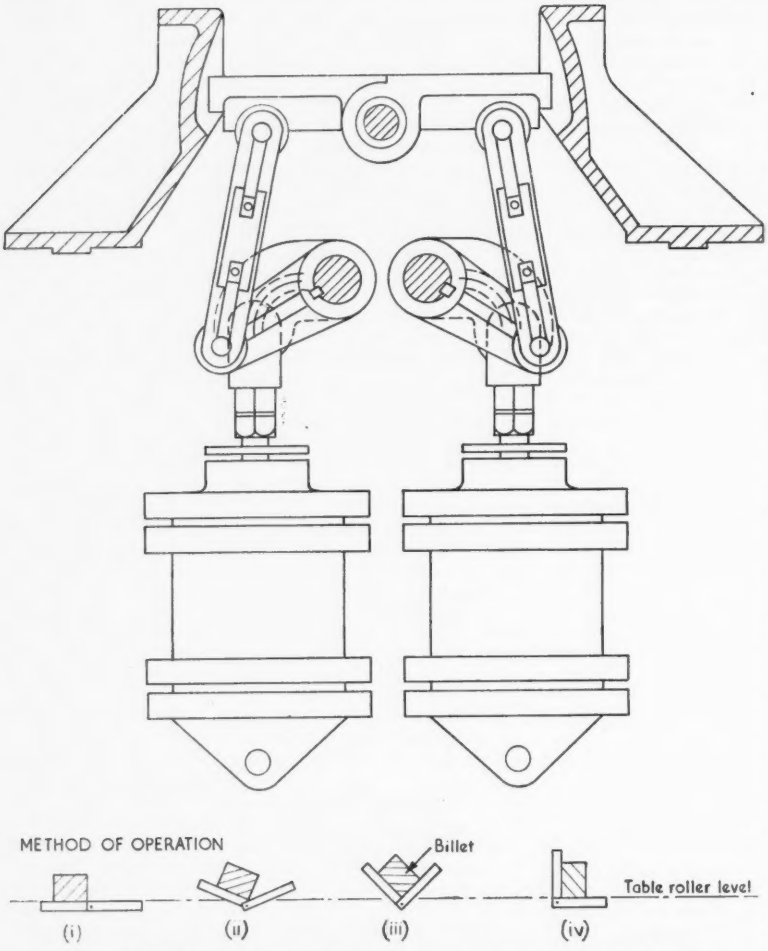


Fig. A—Manipulator for turning billets up to 8 in. square × 7–8 ft. long

whole manipulator can be traversed into line with any desired pass.

In a paper by Peterson, King, and Peterson,* Fig. 10 shows an improved version of the manipulator shown in Fig. 8 of the present paper being used to turn an oval up for a round or square pass. It consists of a pair of shaped rollers set to take the desired bar and mounted on a framework which can be rotated through 90° by a thrustor. Complete automatic operation is obtained by using a photo-electric cell for control.

I should like to confirm that the type of roller entry guides shown in Fig. 20 is used extensively in America with great success. Their application in this country may be limited, particularly on mills rolling fairly short lengths, in that, as Mr. Phipps points out, the first roller is some distance from the roll bite and 12 in. or more of the back-end of the bar is not gripped properly and might therefore be out of gauge. This type of guide can, however, accommodate any whip at the free end of a bar such as occurs after repeating and the bearings do not give much trouble when properly designed. For large bars roller bearings are desirable.

Figure 20 shows diamond-shaped grooves in the rollers. Have these any advantage over oval grooves, apart from the fact that each roller can accommodate a range of bar sizes ?

The mounting of guides is important, particularly in the case of rod mills. On one 3-strand mill, the three guides are mounted together in one casting which has a serrated bottom, fitting into similar serrations on a stainless steel insert in the rest bar. The pitch of the serrations is very accurately cut to correspond with the pitch of the grooves in the roll, and great care is taken to keep the pitch constant. The guide box has only to be lifted and moved along one notch to be set exactly opposite the new holes.

I agree with the author on the value of changing stands in large section mills where a few pass changes in one week can mean the loss of a shift's rolling time.

Mr. **Bailey:** One point which has not been mentioned is entry on the diamond by diabolo rollers. It is a very simple idea and has been done on a recent continuous mill. The bar coming from the blooming mill drops into a diabolo in the roller itself. The variations in pass line from the diabolo roller are easily obtained by using a short swivelling section adjustable for height.

The time taken in changing the complete roll stand has to be off-set against the huge capital cost involved. The cost of a 2-high reversing mill-stand is about £30,000, so that it is a costly item to consider for roll changes, but it is the ideal way if the mill buildings are equipped for it. It must not be forgotten, however, that most mill buildings of that type are put down with 50-ton cranes, and the lifting involved may call for a 100-ton crane or two smaller ones. The cost does not stop at the cost of the mill stands. It should, however, be done with large-output section mills. I have watched stands being changed in less than half an hour, which is a great improvement on the past.

Mr. **W. J. Wigley** (Raine and Co., Ltd.): Mr. French and Mr. Kilby took the view that the design of guides was an engineering problem. Roll designers will agree that they do not wish to have anything whatever to do with the manufacture of them; they have, however, a better idea than anyone else of what the bar is most likely to do when it enters into or is delivered from the rolls, and with that in mind I think that initially at least the problem is for the roll designer, who will pass it on to the engineer to complete the job.

Haphazard building is deplorable; team-work and co-operation between engineer and roll designer are essential.

Mr. French is right that each roll and roll pass should have its own tackle ; it is a point for tabulated stocking.

It is a good idea when rolling a section to see that sufficient tackle is taken over to the mills to finish the rolling of the order and, when the order is finished, to

* E. T. Peterson, L. W. King, and E. C. Peterson, *Iron Steel Eng.*, Oct. 1949, vol. 26, p. 103.

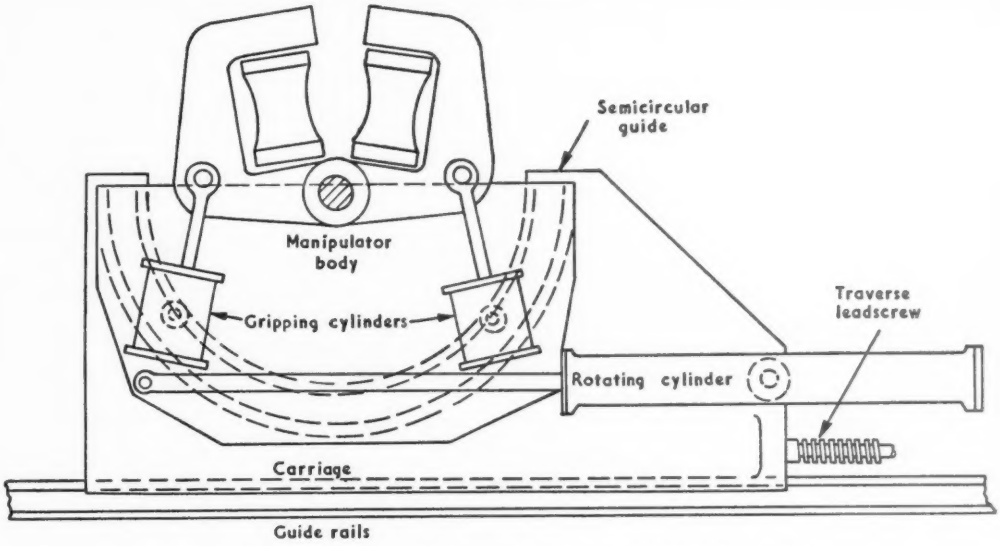


Fig. B—Universal manipulator for a 32-in. 2-high billet mill

bring it back and put back to standard the guide stock for the particular section involved.

Mr. **J. M. McLaughlan** (Appleby-Frodingham Steel Co.): We have installed the device in Fig. 7. It deals with a variety of roughing pass shapes such as tees, flats and many special sections and it can be used as a pusher. It can also deal with the manipulation necessary on a general roughing pair of rolls which takes a $6\frac{3}{4}$-in. square and rolls it down to 3-in. square billets. This would appear to be the limit of its use. It may be necessary to adjust the device mechanically for smaller sizes. In regard to roll changing it is doubtful whether there is a mill in the country in which rolls are being changed as quickly as they are at Appleby-Frodingham. We rarely exceed a 2-stand change although we roll 3-stand sections and the average time per pair is 45 min. The tackle is knocked down and reset in the cramp bars to suit the new rolls being mounted. When cramps and rolls are put in a separate arrangement and the whole is lifted into the mill, what is done if the arrangement which is set up cannot be mounted when a premature change takes place on the section being rolled because of a roll breakage, and the steel in the soaking pits is not of the desired quality ?

Mr. **Bailey:** In my view, the manipulating equipment at the Appleby-Frodingham plant is one of the best in the country. It should be noted that at this plant the first roughing stand pusher has a sliding head with two fingers on it. One will do if only one direction is required. It also has a manipulator which can tilt a channel on its corner and turn it up. On the third stand there is a pusher which is just a head moving across the table and up and down.

Concerning Mr. McLaughlan's problem, surely the rolls in the stand can be changed ?

The **Chairman:** The great thing is to make the stands

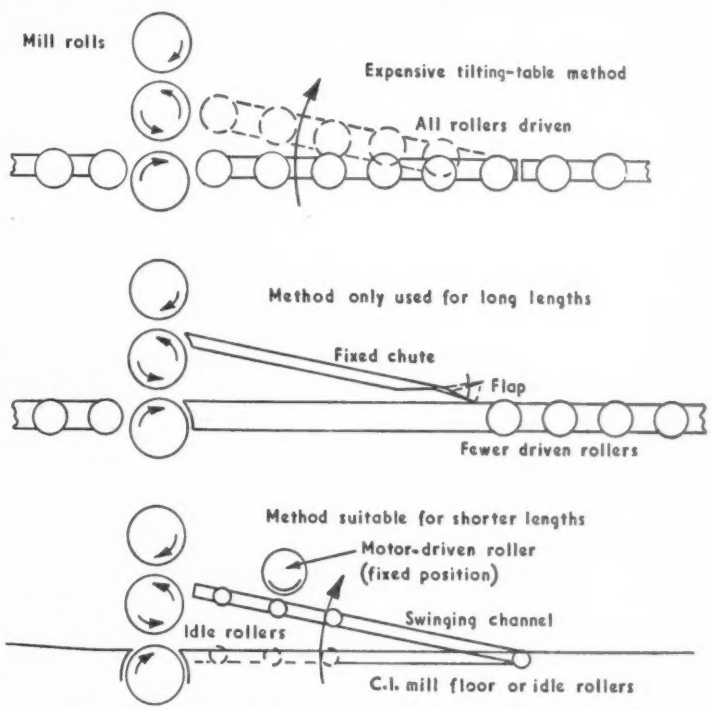


Fig. C—Three methods of manipulation in a 3-high mill

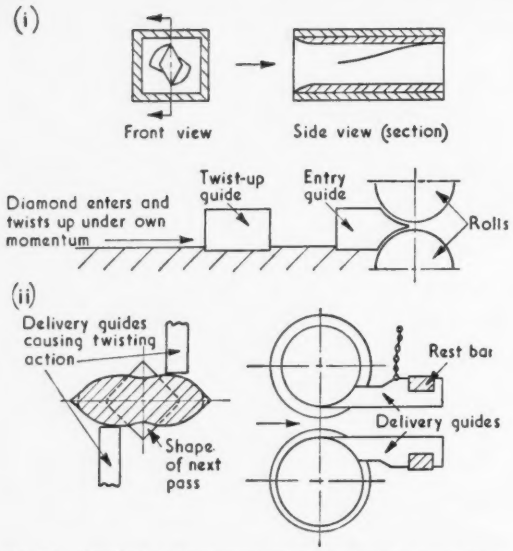


Fig. D—Methods of twisting up stock for the next pass

easy enough for the purpose, in or out of the mill.

Mr. **Bailey:** At the Appleby-Frodingham plant rolls are changed very quickly, and they have closed housings. Some people prefer loose tops.

CORRESPONDENCE

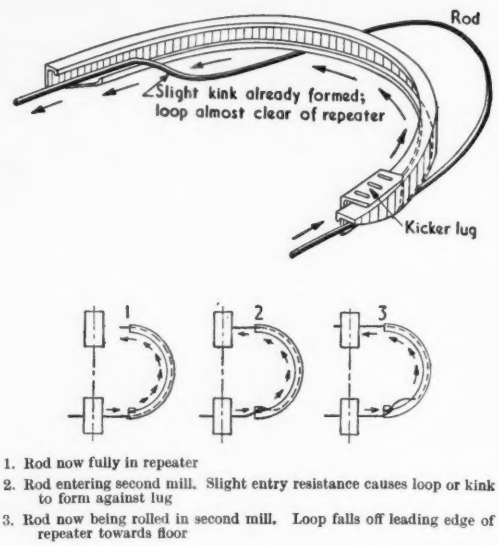
Mr. **N. D. Thomson** (The United Steel Companies Ltd.) wrote: The author has covered the subject in a most admirable way and presented what is in fact a catalogue of auxiliary equipment used for rolling mills. I should like to add to this catalogue three other manipulating devices.

Figure *C* shows manipulation in a 3-high mill by three different methods. The first is by the conventional tilting table with driven rollers. This can be a rather expensive addition to the mill capital costs. For the rolling of long lengths the tilting table with driven rollers can be dispensed with, and a steel channel installed as a run up into the top pair of rolls. A piece is delivered from the bottom pair of rolls and lifts up a flap at the entrance to the fixed channel. This flap falls down as the stock passes it and the driven roller table forces the stock over the flap and up the channel, into the top pair of rolls. This can only be used for lengths which are long enough for the driven rollers to give sufficient momentum to the stock.

In the case of very short lengths where no roller table exists, the lifting operation can be carried out by means of a swinging channel which raises the short length into contact with a rotating roll which by friction drives the stock into the top rolls.

Figure *D* (i) shows a method of twisting up ovals or diamonds into the next pass. The conventional entry guide is fixed at the rolls and in front of this a rigid twist guide is situated. The diamond or oval is thrust into this twist unit (which has considerable clearances) by the roller table and its momentum is sufficient to turn it up and align it with the entry guide. This method avoids working parts and requires no operator specifically for the turn-up device.

Another method of twisting stock up for the next pass is shown in Fig. *D* (ii), where the delivery guides from the previous pass deliberately cause slight twisting of the stock. These guides are set so that there is sufficient twist in the stock to make it lie on the table with the major axis vertical, ready for entry into the next pass. The number of men required to enter the section is thus reduced since no heavy turning up is required.

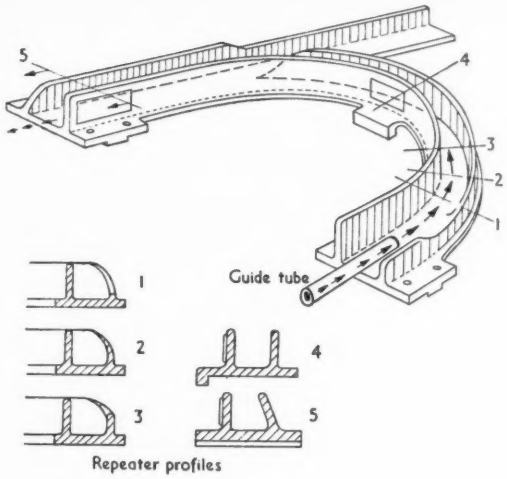


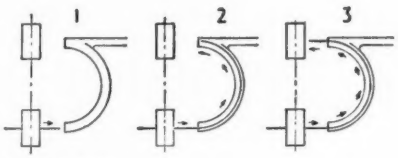
1. Rod now fully in repeater
2. Rod entering second mill. Slight entry resistance causes loop or kink to form against lug
3. Rod now being rolled in second mill. Loop falls off leading edge of repeater towards floor
4. Loop growing further
5. Loop increasing and now on mill floor
6. Loop further increased and portion on floor moving away from mill
7. Loop almost clear of repeater
8. Repeater action now fully complete. Normal growth of fully formed loop continues

Fig. E—Bottom-discharge type repeater for small rod mills

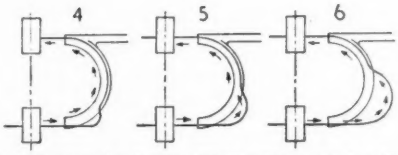
Mr. **C. A. Jobborn** (W. H. A. Robertson and Co., Ltd.) wrote: The following remarks concern mainly the author's note on guides, guards and strippers, in which he says that "heavy bars can be repeated on a comparatively short radius without ill effect on the steel." Would the author amplify the statement and give us the benefit of his experience in the light of the following remarks which apply more to the mechanical aspect of repeating on bar and rod mills.

It is obvious that a limit exists to the size of square or oval that can be repeated on, say, a 14-in. or 16-in. cross-country mill train.

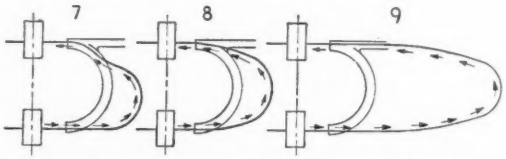




1. Rod about to enter
2. Rod now fully in repeater
3. Rod fully in repeater and about to enter second mill



4. Rod entering second mill rolls. Slight resistance due to entry causes loop to form
5. Rod now being rolled. Loop growing and gradually overflowing
6. Loop growing further



7. Loop growing further and almost leaving the repeater curve
8. Loop about to leave repeater curve completely
9. Repeater action now fully completed. Normal growth of fully formed loop continues

Fig. F—Top-discharge type repeater

Basically, the features affecting repeater action appear to be the amount of traction imparted to the bar when rolling to overcome the rubbing and bending action of the repeater, plus the amount of force required to enter the guide and rolls of the next pair of rolls. The amount of traction is, of course, dependent upon the draft imposed upon the bar by the mill stand delivering the stock into the repeater.

Would the author give some indication of the largest square and oval which are commonplace when rolling an ordinary carbon steel in the average 14-in. mill ?

The following factors are involved in repeater design:

(i) Rolling speed
(ii) Roll diameter
(iii) Drafting
(iv) Shape and area of bar
(v) Position of ' spill ' or relief on the outer edge of the repeater
(vi) Steel quality in terms of resistance to bending.

This is a formidable array of points and perhaps it would be nearer the truth to say that a successful repeater design is the product of operational experience, common sense, and perhaps an intuitive understanding of the behaviour of the material under given conditions.

My own experience of repeaters is very limited; perhaps the author would comment on my impressions of just what happens in a repeater. These have been set out in Figs. *E* and *F*, which show, respectively, the channel type of suspended repeater where the loop drops on to the floorplate, and the more common type of cast repeater where the loop spills over the edge of the groove.

I have not found a description of the operation in any of the technical publications in this country, so I hope to have my impressions either corrected or confirmed.

The suspended-channel type repeater is one seen in Finland a few years ago; it worked very well on squares up to about $\frac{3}{4}$ in. square at 600 ft./min. but became rather erratic when other bars were in adjacent repeaters at the same time.

In this arrangement, all three repeaters on squares were arranged between two 15-in. mill stands and were carried on mild-steel outrigger arms secured to the mill housings from a stool on the mill floor; the probable cause of erratic operation may have been the lack of complete rigidity in the assembly.

I should like to suggest to the author that an illustration of the Williams manipulator would be a valuable addition to his well-written description of how it functions.

I realize that because of other commitments Mr. Bailey was short of time when he was nearing the completion of his work, and it may be that such an illustration was not readily available at that time.

AUTHOR'S REPLY

Mr. **Bailey** (in reply to Mr. Jobborn) wrote: Since giving the paper, I have visited Sweden with Mr. Norlindh of Morgardshammar, whose paper is very helpful.* This company is repeating bars 1·57-in. square on mills with 21·6-in. dia. rolls, and this is the size I referred to ; $2\frac{1}{2}$-in. square is visualized in the future.

The main point of repeating is, of course, that the bar must be long enough to enter the following stand while still in the grip of the preceding pass. This also answers Mr. French's query about Fig. 12. On the Morgardshammar mills several straight passes were made to obtain the length necessary for repeating.

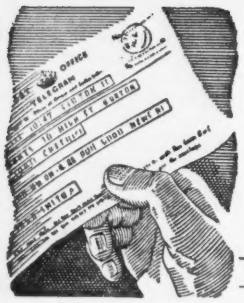
Mr. Norlindh is more able to give figures on this, as my main experience is on smaller mills, such as the Morgan.

In regard to the Williams manipulator, the use is limited, because it grips the piece and does not allow it to run forward to the mill as effectively as the bobbin-type manipulator, such as the Freimel.

Figures *E* and *F* are well illustrated in a paper given to a meeting of the Junior Engineers.†

* S. E. M. Norlindh, *J. Iron Steel Inst.*, 1954, vol. 176, pp. 391–405.

† J. S. Mayne, Meeting of the Junior Engineers at Ashorne Hill, May 11th–14th, 1953.



N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Special Meeting in Sweden, 1954

A Special Meeting of The Iron and Steel Institute is being held in Sweden from **Monday, 7th June, to Friday, 18th June, 1954.** Full details of the programme were given in the May issue of the *Journal*, pp. 191–193.

Autumn General Meeting, 1954

The **Autumn General Meeting** of The Iron and Steel Institute will be held in London on **Wednesday and Thursday, 24th and 25th November, 1954.** Details of the programme will be given in a later issue of the *Journal*.

Symposium on Powder Metallurgy, 1954

The Iron and Steel Institute is organizing a Symposium on Powder Metallurgy, to be held in London on Wednesday and Thursday, **1st and 2nd December, 1954.** Preliminary details of the Symposium were given in the May issue of the *Journal*.

As previously announced, a small exhibition of powder-metallurgy components will be organized; the purpose will be to show, not so much ordinary parts in normal production, but specimens with special characteristics or examples of the application of powder metallurgy to problems difficult of solution by other methods. Any company in the U.K. wishing to display components in this exhibition is invited to submit a list of proposed specimens, with brief details of their particular points of interest, to the Secretary, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1. This will enable the Organizing Committee to select items that may be built up into an exhibition illustrating the present state of development of the production of powder-metallurgy components in the U.K. The Committee reserves the right to accept or reject exhibits at its discretion.

Joint Metallurgical Societies' Meeting in Europe, 1955

The American Institute of Mining and Metallurgical Engineers and the American Society for Metals have accepted invitations from certain metallurgical societies in Great Britain, France, Germany, and Sweden to send representatives to a Joint Metallurgical Societies' Meeting in Europe in June, 1955. The approximate dates of the main meeting are 1st–7th June in Great Britain, 9th–12th June in Düsseldorf (Germany), and 14th–19th June in Paris. An opportunity will be provided for visiting Liège (Belgium) *en route* from Düsseldorf to Paris on 13th June. Tours will be arranged to other European countries after the conclusion of the main meeting.

The arrangements in Great Britain are being made jointly by The Iron and Steel Institute and the Institute of Metals. The following continental societies are associated with them in issuing the invitation to the American societies; The Société Française de Métallurgie (France), Verein deutscher Eisenhüttenleute, and Deutsche Gesellschaft für Metallkunde (Germany), and Jernkontoret (Sweden).

The objects of the meeting are to establish personal contacts between experts in the U.S.A. and in Europe, to provide opportunities for scientific and technical discussion, to enable visitors from the U.S.A. to see something of the metallurgical industries of Europe and to visit places of historical and other interest, and to foster better understanding and co-operation among all concerned.

A detailed list of subjects for discussion will be announced later. They will include various aspects of iron- and steel-making, rolling and forging (but not casting), refining and fabrication of non-ferrous metals, heat-treatment, metallurgical education, and research.

Much of the technical and scientific work of the meeting will be conducted by means of discussion groups, but certain plenary sessions and formal meetings for the presentation and discussion of papers will also be held. The meeting will begin with a Plenary Session in London on Wednesday, 1st June. During the following days, in addition to technical meetings, visits will be paid to laboratories and works and places of general and historical interest in the neighbourhood of London; opportunities for informal discussion will be provided at social functions in the evenings. Visitors from the U.S.A. will be given an opportunity to take part in alternative tours of industrial districts before leaving for the Continent on 8th June. Special arrangements will be made for ladies.

By agreement with the American Societies, the total number of visitors from the U.S.A. will be restricted to 350. Representation of European Societies will be arranged by personal invitation. The opportunities that will be provided for members of British Institutes to meet these visitors from the U.S.A. and the Continent will be announced later.

All communications should be addressed to The Honorary General Secretary of the European Committee (K. Headlam-Morley), c/o The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1. Further information will be given in later issues of the *Journal*.

Changes on Council

The following have accepted invitations to serve as Honorary Members of Council during their periods of office:

Mr. F. H. Saniter, (Member of Council), President of the Sheffield Metallurgical Association

Dr. S. F. Dorey, C.B.E., F.R.S., President of the Institute of Metals

Mr. R. E. S. FISHER, President of the Sheffield Society of Engineers and Metallurgists

Mr. K. G. LEWIS, President of the Staffordshire Iron and Steel Institute

Mr. J. D. HANNAH, President of the Manchester Metallurgical Society.

NEWS OF MEMBERS

▶ Dr. W. F. CHUBB has joined the staff of A. and G. Price Ltd. in an executive capacity, and is now living at Thames, New Zealand.

▶ Monsieur B. DUPUIS has taken up an appointment with the Compagnie des Ateliers et Forges de la Loire at Le Boucau, France.

▶ Mr. F. FLUBACHER has left the U.K. to take up an appointment with George Fischer Ltd., Schaffhausen, Switzerland.

▶ Mr. W. S. GIFFORD has resigned from his position as Joint Managing Director of the Electric Furnace Co. He will remain on the Board of the Company and of its subsidiaries, Electric Resistance Furnace Co., Ltd., and Electro-Chemical Engineering Co., Ltd.

▶ Mr. E. GREGORY has been awarded the degree of Ph.D. of the University of Cambridge.

▶ Dr. J. B. HAWORTH has left Sheepbridge Engineering Ltd. to take up an appointment with the British Columbia Research Council in Vancouver.

▶ Mr. H. W. G. HIGNETT, Superintendent of the Development and Research Laboratory of the Mond Nickel Co., Ltd., has been appointed to the Board of Henry Wiggin and Co., Ltd., and will take charge of technical (metallurgical) control in all the Wiggin plants. He is succeeded as Superintendent of the Laboratory by Mr. H. EVANS. Mr. O. LEWIS JONES becomes General Production Manager, and will be responsible for production in all the Wiggin plants.

▶ Dr. J. F. HYSLOP, Mr. J. YOUNG, and Mr. R. MALCOLM have been appointed Executive Directors of John G. Stein and Co., Ltd.

▶ Mr. H. JENSEN has left the Siam Cement Co., Ltd., to take up an appointment with F. L. Smidth and Co. A/S., Copenhagen, Denmark.

▶ Mr. E. F. MACTAGGART has sold his interest in the Sondes Place Research Institute, of which he has been Director for the past seven years, and has resigned from the Board of Mactaggart and Evans Ltd.

▶ Mr. S. P. MAYNARD has been appointed Director and Chief Engineer of the Igranic Electric Co., Ltd.

▶ Mr. JAMES MITCHELL, C.B.E., immediate Past-President of the Institute, has retired from his position as Managing Director of Iron and Steel Production at Stewarts and Lloyds Ltd. He will remain a Director of the Company. He has been succeeded by Mr. W. C. BELL, who together with Mr. E. G. SAUNDERS has been appointed to the Board. Mr. G. S. MCLAY has retired from his Directorship.

▶ Mr. G. MOSTART has been appointed a Director of Powell Duffryn-Coppee Ltd.

▶ Mr. J. M. MOWAT has been appointed a Director of William Beardmore and Co., Ltd. He will also continue as Chief of Research.

▶ Mr. M. D. PATWARDHAN has been awarded the degree of Ph.D. of the University of Leeds.

▶ Monsieur P. F. PINGUAULT has taken up an appointment with the Compagnie des Ateliers et Forges de la Loire at Saint-Chamond, France.

▶ Mr. S. V. RAMAN has joined Mannesman Hüttenwerke A.G., Duisberg-Hückingen, Germany.

▶ Mr. C. H. SHIRTCLIFFE, Chief Metallurgist to the Pakistan Ordnance Factories, has been awarded the M.B.E.

▶ Mr. J. E. SRAWLEY has joined the Meehanite Metal Corporation, New York, as a development engineer.

▶ Mr. J. W. S. STAFFORD is now a Research Metallurgist in the Research Laboratories of Wm. Jessop and Sons, Ltd.

▶ Mr. R. W. STOBBS has left the David Brown Foundries Co. to join the Plessey Co., Ilford.

▶ Mr. B. THORNTON has resigned his Directorship of the Wellman Smith Owen Engineering Corporation Ltd.

Obituary

Dr. KOTARO HONDA, Bessemer Gold Medallist in 1922, on 12th February, 1954.

Mr. S. F. KEENER, of the Keener Industries, Ohio, U.S.A., on 2nd April, 1954.

Mr. A. E. PARKER, of Scrivener, Breffit and Co., on 21st March, 1954.

Mr. THOMAS POLLOCK, of Sutton Coldfield, on 2nd March, 1954.

Mr. W. P. SNEDDEN, Chief Technical Engineer of the Rolling Mill Division of British Timken Ltd., on 23rd April, 1954.

CONTRIBUTORS TO THE JOURNAL

R. A. Owen-Barnett

R. A. Owen-Barnett, B.Sc.—Assistant to the Director of Research, Whitehead Iron and Steel Co., Ltd.

Mr. Owen-Barnett was born in 1922. He was educated at Penarth County School and at the University College of South Wales and Monmouthshire, Cardiff, where he graduated in Metallurgy in 1943. After graduation he spent two years as a Plant Control Metallurgist with the Northern Aluminium Co., Ltd. He joined the Whitehead Iron and Steel Co., Ltd., in 1946.

E. W. Williams, M.Sc.—Research Fellow at the Ontario Research Foundation, Toronto.

Mr. Williams was born in 1929. He was educated at Ffestiniog Grammar School, and at University College, Swansea, graduating with 1st Class Honours in Metallurgy in 1950. After a period of training in the Research Department of Metropolitan-Vickers Electric Co., Ltd., he returned to University College, where he carried out research with the electron microscope. He was awarded the degree of M.Sc. in 1953.

Mr. Williams went to Canada in 1952 to take up a post as Research Engineer with the International Nickel Co., at Sudbury, Ontario. A year later he was awarded a Fellowship at the Ontario Research Foundation, and is now a member of a team carrying out work on the development of controlled-density steels.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Staff Changes

Dr. H. L. SAUNDERS, who has been Head of the Association's Ironmaking Division since its establishment in 1945, retired at the end of April owing to ill health. He is succeeded by Mr. E. W. VOICE, who was formerly Assistant Director of Central Research Establishment

(II), National Coal Board. Mr. Voice took up his appointment on 1st June.

The temporary appointment of Dr. J. PEARSON as Head of the Steelmaking Division has been made permanent. He will continue to combine the appointment with that of Head of the Chemistry Department.

Diamond Die Profiloscope

An instrument recently manufactured by the Association is the diamond die profiloscope. This simple instrument facilitates rapid inspection of the interior of wire-drawing dies down to 0·002 in. in diameter. It is a development of the earlier wire-drawing die profiloscope, which could be used for dies of 0·04 in. in diameter.

NEWS OF SCIENCE AND INDUSTRY

Society of Chemical Industry

The Corrosion Group of the Society of Chemical Industry is holding a Joint Conference with the Association Belge pour l'Étude, l'Essai, et l'Emploi des Matériaux in Brussels, on 1st–4th June, 1954. Papers on the fundamental and practical aspects of corrosion will be discussed, and the programme will include works visits to corrosion test-sites, factories, and laboratories.

Exchange and Engineering Centre

The new Exchange and Engineering Centre at Birmingham will be opened in June, 1954. It will be Britain's only permanent engineering centre, and a wide variety of medium and light engineering products will be exhibited.

Institute of Physics

The Industrial Radiology Group of the Institute of Physics has recently been reconstituted as the Non-Destructive Testing Group. Under its new title, the Group will hold its Summer Meeting at Chancellor's Hall, University of Birmingham, on 7th–10th July, 1954. The meeting will be divided into six sessions: Isotope techniques, image intensifiers; diffraction mottling; theory and application of electrical and magnetic methods of non-destructive testing; propagation of elastic waves in solids; and selected topics in ultrasonic testing.

World Power Conference

A Sectional Meeting of the World Power Conference will be held in Rio de Janeiro, Brazil, from 25th July to 10th August, 1954. It is expected that the Conference proper will take place during the week 25th to 31st July, and during the following ten days the Brazilian National Committee hope to organize tours to electrical installations in the country. Anyone wishing to attend the Conference should immediately notify the Secretary, British National Committee, World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2.

Metallurgical Applications of X-ray Diffraction

A two-week special Summer Programme on the metallurgical applications of X-ray diffraction will be held at the Massachusetts Institute of Technology on 2nd–13th August, 1954.

British Association for the Advancement of Science

The 116th Annual Meeting of the British Association for the Advancement of Science will be held at Oxford on 1st–8th September, 1954. In addition to specialist section meetings, the programme will include film shows, visits to places of interest in the Oxford area, non-specialist lectures, and exhibitions of general or sectional interest, to be held in Oxford. Full particulars of the Meeting may be obtained from the Secretary, British Association for the Advancement of Science, Burlington House, London, W.1.

Summer School in Mineral Dressing

A Summer School in Mineral Dressing will be held in the Bessemer Laboratory of the Royal School of Mines, from 14th to 17th September, 1954. The course will include lectures covering comminution, classification, grinding control, gravity separation, flotation, and ancillary processes, and will be illustrated by films, demonstrations, and class work. The work will start daily during this period at 10 a.m. and will finish at 5.0 p.m. Application forms may be obtained from the Registrar, Imperial College, Prince Consort Road, London, S.W.7. The fee for the course is £10 10*s*. 0*d*.

Corrosion Congress

The Working Party on Corrosion of DECHEMA, which held its last meeting as an international body in 1943, has resumed its activities and will hold a Congress on Corrosion in Frankfurt-am-Main on 11th–12th November, 1954. This Congress will also form the Annual General Meeting of DECHEMA.

Research Fellowship in Metallurgy

Applications are invited for a Research Fellowship of the Armourers and Brasiers' Company. The successful candidate will be required to devote his whole time to a course of research which must be connected with base metals and alloys, preferably those used in connection with the Ancient Crafts of the Company of Armourers and Brasiers. The appointment will be for two years in the first instance, as from 1st October, 1954, but it may subsequently be extended to a maximum of five years. The stipend will be £850 per annum.

Applications must be received at the Royal Society by not later than 12th June, 1954. Applicants will be required to give three references and to furnish particulars of their academic qualifications and of research work already carried out by them. They should also give an outline of the research work that they propose to undertake. Further particulars and forms of application may be obtained from the Assistant Secretary, The Royal Society, Burlington House, London, W.1.

Insignia Award in Technology

The Executive Committee of the City and Guilds of London Institute have authorized an amendment to the regulations governing the award of the Institute's Insignia Award in Technology. The amended regulation (3c) now reads: " *For an interim period, however, candidates may be accepted for consideration if they have gained an approved group of qualifications preferably awarded by the Institute.*" The amendment consists of the addition of the word " preferably." Thus, for an interim period, candidates need not be refused registration because they hold no Full Technological Certificate or other City and Guilds Certificate qualification, provided they are in possession of others that are deemed acceptable by the Committee.

Sidney Gilchrist Thomas Medal

A ' Sydney Gilchrist Thomas Medal ' has recently been inaugurated at the University College of Swansea. The Medal, which is the result of a gift by Mr. A. G. Robiette,

a former student of the College, will be awarded annually to the best student in the graduating year of the Department of Metallurgy.

United Steel Companies' Scholarships

The United Steel Companies, Ltd., have endowed a University entrance Scholarship, tenable at St. John's College, Cambridge, which will be open to candidates intending to study Physical or Mechanical Sciences. The Scholarship will be offered annually at the open examination for Entrance Scholarships and Exhibitions of the College, and the emolument will be £100 a year; the College will be entitled to augment this to bring it up to a total value of £150.

Beilby Memorial Awards

The Administrators of the Sir George Beilby Memorial Fund recently considered the claims for an award from the Fund of candidates whose merits had been brought to their attention. The Committee was impressed by the promise shown by several of these candidates, but concluded that none of them adequately fulfilled the conditions of the award, which is made " in recognition of continuous work of exceptional merit, bearing evidence of distinct advancement in science and practice."

It was decided, therefore, to make no award for 1953 but to let it be known that this decision should not discourage future applications by or on behalf of the present candidates or other investigators working on subjects relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering, and metallurgy.

New Metallurgy Building at N.P.L.

A new extension to the Metallurgy Division of the National Physical Laboratory was opened on 6th April, 1954, by Sir Lawrence Bragg, O.B.E. The extension has been made necessary by the continuous development of techniques for the study of the fine structure of metals, and the growth of interest in the properties of materials at very high temperatures. It consists of a two-storey building which will accommodate the ceramics and X-ray sections of the Division, and a new radioactive tracer section. The latter will have facilities for carrying out on metals of all but the highest activity most of the operations normally applied to metals in a research laboratory, and quantities of up to about 6 lb. of active metal may be handled. It is proposed to offer these facilities to workers in other metallurgical laboratories, and also to undertake work on problems submitted by outside organizations.

Model Ore-Handling Plant

A complete working model ore-handling plant has been manufactured by the Moxey Conveyor Co., Ltd., and will be on show at the Mechanical Handling Exhibition, to be held at Olympia, London, on 9th–19th June, 1954. The model, which is based largely on the system of ore unloading, stocking, and reclaiming used by the Consett Iron Co., Ltd., shows clearly the whole process from the discharging of trains to the feeding into blast-furnaces.

Canadian Institute of Mining and Metallurgy

The Canadian Institute of Mining and Metallurgy, which has formerly been essentially interested in the mining industry, is being developed to serve in addition the iron and steel industry. The first branch of the Institute has recently been formed in Hamilton, the centre of the iron and steel industry in Canada. It will be named the Hamilton Iron and Steel Branch, and will be devoted entirely to the technical aspects of iron and steel production and fabrication, functioning in a similar way to The Iron and Steel Institute in Britain and the American Institute of Mining and Metallurgical Engineers. The Bulletin of the Canadian Institute of Mining and Metallurgy has been made available for the publication of technical articles emanating from the Branch.

The First Half Century

The fiftieth anniversary of the foundation of the Institute of British Foundrymen has been commemorated by the publication of the history of the Institute, written by the Secretary, Mr. T. Makemson, O.B.E.

The booklet traces the development of the Institute from the original British Foundrymen's Association, and describes in detail the services that it now renders to its members.

W. Edwards and Co., Ltd.

The new Allendale Works of W. Edwards and Co. (London), Ltd., were opened on 5th March, 1954, by Sir Ben Lockspeiser, Secretary of the Scientific Advisory Council of D.S.I.R. The new works, which are at Crawley, Sussex, are fully equipped and provide adequate accommodation for the Company's research and development projects. The layout of the laboratories is standardized, writing and discussion rooms are provided for each section of the laboratories, and there is a well-equipped library. The workshops have been specially designed for the precision production of scientific apparatus and equipment.

Supplies of Molybdenum

Since the lifting of restrictions on the use of molybdenum (reported in the November, 1953, issue of the *Journal*, p. 325), the Climax Molybdenum Company of Europe Ltd. have expanded their production so that the anticipated output in 1954 is 42½ million pounds. It is considered that all demands for the metal can be met.

Sorting and Testing of Ferro-Magnetic Materials

A new device for the rapid and accurate sorting and testing of ferro-magnetic materials has recently been produced by Solus-Schall Ltd. Known as the ' Magnatest Q,' the device can sort finished and semi-finished parts of up to 12 in. in diameter according to quality (composition, texture, cracks), heat treatment, hardness, depth of case hardening, surface decarburization, tensile strength, ductility, and deep-drawing properties.

D.S.I.R. Annual Report

The Advisory Council of the Department of Scientific and Industrial Research has issued its report for the year 1952–53. The report, Comd. No. 9083, gives details of a plan for the growth of D.S.I.R. over the next five years. It is obtainable from H.M.S.O., price 8*s*. (by post 8*s*. 6*d*.).

Properties of Tin

The Tin Research Institute has issued a revised edition of the booklet, " *The Properties of Tin*," which was first published in 1934. The new edition aims to present all published atomic, nuclear, physical, physico-chemical, and metallurgical data for pure tin, but does not deal with tin alloys. The information is given under eight main headings: Atomic and nuclear properties, line spectra, X-ray data, crystallography, optical properties,

electrical and magnetic properties, thermal properties, and mechanical properties. Copies of the book are obtainable from the Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex, price 2*s*. 6*d*.

Associated Electrical Industries

"*Review of the Year* 1953," published by the Associated Electrical Industries, Ltd., gives details of the work completed by the Group during the past year, with examples of the uses of many of the products of firms within the Group. In his statement the Chairman, Sir George Bailey, C.B.E., mentions orders from the British Electricity Authority, the National Coal Board, and other authorities. The second half of the report gives illustrated examples of A.E.I. equipment for use in the supply of power, the production of materials, world transport, X-ray and medicine, and overseas markets.

Tubular Equipment

The lightness, rigidity, strength, and torsional resistance of steel tubes makes them particularly suitable for materials-handling equipment. They are easy to handle and to paint, and the small surface area reduces maintenance costs. In a booklet entitled "*Some Examples of Tubular Equipment for use in Materials Handling*," Tubewrights Ltd. give details of various applications of steel tubes manufactured by the Company, and of a system by which a range of materials-handling equipment can be built up from standard components.

Induction Heating System

Kestner Evaporator and Engineering Co., Ltd., have acquired the exclusive rights of the Wild-Barfield Induction Heating System for applications in the chemical and allied industries. The System has for some time been successfully applied to the heating of metals for forging, billet heating, and heat treatment.

Film on Induction Heating Processes

A new 16-mm. sound film in colour entitled "*The Tocco Story*" has recently been received from the U.S.A. by the Electric Furnace Co., Ltd. The film gives a pictorial survey of H.F. induction heating processes and the products of the Tocco Division of the Ohio Crankshaft Company of Cleveland, Ohio. It may be borrowed, free of charge, by technical societies, schools and universities, and industrial concerns interested in H.F. heating; application should be made at least a fortnight before the intended date of showing, to Electric Furnace Co., Ltd., Netherby, 161 Queens Road, Weybridge, Surrey.

Sulzer Brothers

Sulzer Bros., Ltd., of Winterthur, Switzerland, have recently issued a comprehensive booklet on the Company. It is divided into two sections, "*Historical Retrospect*" and "*Technical Developments*," and is fully illustrated.

Industrial Publications Received

▶ '47 Monolith' ladle lining—Characteristics and applications—Chambers Bros., Ltd.

▶ Bailey temperature indicators—Leaflet No. M 19—Bailey Meters and Controls Ltd.

▶ Stainless, Corrosion and Heat Resisting Steels. Ranges, properties, and applications—Publication No. CH/C 2204—Darwins Ltd.

▶ Crude Gas Slide Valves—Zimmerman and Jansen G.m.b.H. (obtainable from D.M.M. (Machinery) Ltd.).

▶ Iron Castings (Publication No. 114)—Steel Castings (Publication No. 115)—Heavy Weldments (Publication No. 116)—Davy and United Engineering Co., Ltd.

▶ Darwins Ltd. have recently issued a brochure giving details of the extended range of quality steels and of rolled and forged bars now manufactured by the Company—Publication No. WH/C.2205.

▶ Martonair Pneumatic Equipment—Catalogue section dealing only with small cylinders and valves useful for jig and fixture designers—Martonair Ltd.

▶ Brochure on industrial pipework—William Press and Son, Ltd.

▶ Heat Treatment of Steel—A short technical description of the more usual methods of heat-treatment—Uddeholm Ltd.

▶ Hiduminium Aluminium Alloys and their Foreign Equivalents—High Duty Alloys Ltd.

Changes of Address

The Sheffield office of the WOODALL-DUCKHAM CONSTRUCTION CO., LTD., has been closed. All business formerly dealt with there will now be handled by the Company's representatives at 22 St. Anne's Square, Manchester, 2, or at 1 Castle Street, Edinburgh, 2.

Messrs. HONEYWELL-BROWN LTD. have opened a new office at 35 Byrom Street, Manchester, 3. The new office will deal with business from Cumberland, Westmorland, Lancashire, Cheshire, and N. Wales.

TEKON LTD. have removed to new offices at 50 Baker Street, London, W.1 (Tel. Welbeck 6175).

DIARY

1st–2nd June—SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—Joint Conference with the Association Belge pour l'Étude, l'Essai et l'Emploi des Matériaux—Brussels.

7th–10th June—INSTITUTE OF PHYSICS (Non-Destructive Testing Group)—Summer Meeting—Chancellor's Hall, The University, Birmingham.

7th–18th June—THE IRON AND STEEL INSTITUTE—Special Meeting in Sweden.

9th–19th June—Mechanical Handling Exhibition and Convention—Olympia, London.

23rd–25th June—Seventeenth Congress for the Advancement of Spectrographic Methods—Paris.

30th June—INSTITUTE OF METALS—"*The Brittle Fracture of Metals: Some New Developments*," by E. Orowan—4 Grosvenor Gardens, London, S.W.1, 5.0 P.M.

4th–10th July—BRAZILIAN ASSOCIATION OF CHEMISTRY—11th Brazilian Chemical Congress—Sao Paulo.

6th–9th July—INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS—Commission on Electron Microscopy—London.

7th–10th July—INSTITUTE OF PHYSICS (Non-Destructive Testing Group)—Summer Meeting—Chancellor's Hall, University of Birmingham.

TRANSLATION SERVICE

(The previous announcement was made in the May, 1954, issue of the *Journal*, p. 200).

TRANSLATION AVAILABLE

No. 486 (German). W. RIEMANN: "The Significance of Fuel Economy in Hot-Working Operations in a Works Making Special Steels." (*Stahl und Eisen*, 1953, vol. 73, May 21, pp. 721–727).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for translations is £1 for the first copy and 10*s*. for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUESTS—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS AND BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

CONTENTS

	PAGE
Mineral Resources	261
Ores—Mining and Treatment	261
Fuel—Preparation, Properties, and Uses	262
Refractory Materials	263
Blast-Furnace Practice and Production of Pig Iron	263
Treatment and Use of Slag	264
Production of Steel	265
Production of Ferro-Alloys	266
Foundry Practice	266
Heating Furnaces and Soaking Pits	271
Heat-Treatment and Heat-Treatment Furnaces	271
Forging, Stamping, Drawing, and Pressing	273
Rolling-Mill Practice	274
Machinery for Iron and Steel Plant	276
Lubricants and Lubrication	276
Welding and Flame-Cutting	276
Machining and Machinability	277
Cleaning and Pickling	277
Protective Coatings	278
Powder Metallurgy	279
Properties and Tests	280
Metallography	288
Corrosion	290
Analysis	291
Historical	292
Economics and Statistics	292
Miscellaneous	292
Book Notices	292
New Publications	295

MINERAL RESOURCES

Ferrous Metallurgy and Minerals of the Lorraine. (*Echo Mines*, 1953, Aug., 525–528). A description of the principal areas of the Lorraine district where iron ore is being mined is given. The geology of the deposits and the analysis of the ore are considered. A survey of the iron ore reserves in the Lorraine district is made.—B. G. B.

The Mineral Resources and Iron and Steel Industry of Latin America. (*Echo Mines*, 1953, Oct., 653–655). The present state of the iron and steel industry and of the exploitation of mineral deposits in Argentina, Chile, Brazil, Columbia, Mexico, Peru, Uruguay, and Venezuela are reviewed.—B. G. B.

ORES—MINING AND TREATMENT

Eagle Mountain Helps Kaiser Meet Growing Western Steel Needs. K. B. Powell. (*Min. Eng.*, 1953, **5**, May, 478–483). Details are given of all aspects of the mining operations at Eagle Mountain, which commenced in July 1952. The higher grade ores are hard Fe_2O_3 and Fe_3O_4. Accounts are also given of the geology and exploration of the deposits. Ore is despatched at −10 in. size for the Fontana blast-furnaces.

Exploitation of Iron Ore from Cockatoo Island (Australia). M. de Buccar. (*Echo Mines*, 1953, Oct., 651–652). A short account of the mining and transport of high-grade iron ore from this island off the N.W. coast of Australia, is given.

The Sirigao Iron Ore Mine, Goa. (*Min. J.*, 1953, **241**, Dec. 25, 753). A very short description of the first mechanized iron ore mine in Portugese India, is given, together with details of the mechanization scheme, and the various transportation units employed.—B. G. B.

C. F. & I.: Raw Materials: Western Operations. G. H. Rupp, R. L. Hair, and M. L. Sisson. (*J. Met.*, 1953, **5**, Oct., 1313–1316). Brief descriptions are given of the operations at the three iron-ore mines and five coal mines supplying the Colorado Fuel and Iron Corporation's Pueblo plant. The quality of the raw materials and their treatment are outlined.

C. F. & I.: Raw Materials: Eastern Operations. F. Coburn. (*J. Met.*, 1953, **5**, Oct., 1317–1319). A brief description is given of the Richard magnetite iron ore mine in New Jersey, serving the Colorado Fuel and Iron Corporation's Eastern iron and steel plants. The mine produces 1000 tons of crude ore and 640 tons of finished ore daily.—G. F.

Iron-Ore Mining and Preparation at the Austrian "Steirischer Erzberg" Mine: Combined Open-cast, Underground, and Funnel Methods of Ore Extraction. A. Kern and B. Vogl. (*Iron Coal Trades Rev.*, 1953, **167**, Dec. 4, 1285–1289). The authors describe the combination of open-cast, underground, and funnel methods of extracting the high-grade iron ore from the 'ore mountain' in Austria. The layout of the ore preparation plant and the processes employed are outlined, and figures illustrating quality and quantity of the ore are given.

The Iron Ore Mining of Itabira in the State of Minas Gerais, Brazil. C. Effenberger. (*Glückauf*, 1953, **89**, Nov. 21, 1180–1185). The occurrence, geological formation, composition, and beneficiation of the Itabirite hematite deposits is described. A high proportion of fines of high quality is obtained; the advantages of this material for sintering are indicated. Production and export figures are given.—L. D. H.

Improving Narvik Port Loading Installations. K. Idel. (*Demag News*, 1953, (131), 16–18). An account of extensions being made to the existing iron ore loading facilities at Narvik to improve the stocking and loading capacities of the port is given.—B. G. B.

Discharging Iron Ore: Factors Influencing Overall Costs. R. T. Eddison and D. G. Owen. (*Operational Research Quarterly*, 1953, **5**, Sept., 39–50; *Iron Coal Trades Rev.*, 1953, **167**, Dec. 18, 1421–1423). A survey has been made of the operation of importing iron ore in order to determine the best organization to keep costs as low as possible. Factors affecting the total cost are considered, and port congestion delays are discussed. Predictions of the effects of changing certain variable factors are made.—G. F.

Belt Capacity in Conveyor Transport. A. Grierson. (*Min. J.*, 1954, **242**, Jan. 1, 14–16). Methods and equipment used in loading and load control are discussed in detail. A formula for the calculation of the capacity of belts in tons per hour is given and the use of weighing devices and sequence control is discussed.—B. G. B.

Aspects on Pelletizing of Iron Ore Concentrates. M. K. Tigerschiöld. (*J. Iron Steel Inst.*, 1954, **177**, May, 13–24). A brief survey is made of the general development of the method of agglomeration of iron ore concentrates in Sweden, and a report is given of the theoretical work done in Sweden and in other countries in regard to the factors affecting the performance of the pelletizing method. The technical development of the shaft-furnace process is also reviewed, and future uses of the method are suggested. There is still much work to be done in laboratories, as well as on the design and operation of full-scale furnaces, but it seems clear that pelletizing in shaft furnaces will become an important complement to existing methods of agglomeration. This will be

the case especially when utilizing rich magnetite concentrates. For treating hematite concentrates, pyrite residues, and not too rich magnetite concentrates that tend to stick, the use of sintering machines for baking the pellets might be a solution.

Aspects of Swedish Iron Ore Concentration. P. G. Kihlstedt. (*J. Iron Steel Inst.*, 1954, **177**, May, 63–75). The paper gives a survey of the present conditions influencing Swedish iron-ore beneficiation. The choice of iron contents in the concentrates obtained from different types of ore has been investigated in regard to the best possible adaptation for the coke blast-furnace process as applied in Sweden. To help in this study, an evaluation formula for concentrates is submitted, based on production costs of pig iron, and by this formula certain optimum calculations, comparisons between different types of ores, and 'cut-off grade' calculations have been carried out. Furthermore, the importance is discussed of high concentration for the utilization of Swedish apatite iron ores in domestic pig-iron production, which is mostly based on low-phosphorus raw materials, and for Swedish sponge-iron production. It is finally demonstrated that flotation methods would raise the iron recovery in the beneficiation of hematite ores.

The Development of a Pelletizing Process for Fine Iron Ores. J. M. Ridgion, E. Cohen, and C. Lang. (*J. Iron Steel Inst.*, 1954, **177**, May, 43–63). An account is given of laboratory and pilot-scale work on the pelletizing of Sierra Leone and Sydvarangar concentrates and on flash-roasted pyrites residues. Experiences with a vertical-shaft kiln rated at ½ ton/hr. using external gas firing and incorporated solid fuel are related. Studies have been made of the structures of the pellets using microradiographic techniques. Economic aspects are considered in relation to the prospects of the process in the U.K.

The Pelletizing of Northampton Sand Ironstone by Vacuum Extrusion: The Experimental and Pilot Plants at the Corby Works of Stewarts and Lloyds Ltd. A. Stirling. (*J. Iron Steel Inst.*, 1954, **177**, May, 25–42). The essentials of the vacuum-extrusion pelletizing process are outlined and its application to the ironmaking practice based on low-grade Northamptonshire ores, at Corby, is stated. The equipment of an experimental and a (later) pilot plant are described and details are given of their operation in relation to the physical properties of the raw material and the products. The enrichment of the Northamptonshire ore pellets by additions and by high-temperature firing is discussed and the conditions necessary for sulphur removal are given. In a concluding section the development of the process at Corby is assessed.

A Method of Automatic Control for Sinter-Plant Feeder Tables. S. K. Dean, W. N. Jenkins, P. K. Gledhill, and A. J. Blanchard. (*J. Iron Steel Inst.*, 1954, **177**, June, 220–223). [This issue].

FUEL—PREPARATION, PROPERTIES, AND USES

Flame Stability Studies of Different Vaporized Fuels under Non-Homogeneous Mixing Conditions in a Small Scale Combustion Tube. J. G. Kirtley and A. Lewis. (*Fuel*, 1954, **33**, Jan., 5–19). The flame stability limits of a number of fuels in vapour form have been determined using a small quartz combustion chamber with heterogeneous air-fuel mixing conditions. With isomeric fuels the limit differences become appreciable only at extreme air flows, where the limits appear to be dependent on the ease of oxidation of the fuel.—B. G. B.

Flame Radiation Research Joint Committee: Reports of Burner Trials at Ijmuiden. (*J. Inst. Fuel*, 1953, **26**, Oct., 189–224). A further series of reports on the work of the Flame Radiation Research Joint Committee is presented under this general heading. For abstracts of earlier papers see *J. Iron Steel Inst.*, 1953, **173**, Feb., 192. Abstracts of the present reports follow:

Introduction. M. W. Thring. (189–192). It is explained that 'Performance Trials' were carried out to ascertain the external properties of a large number of flames, and 'Combustion Mechanism Trials' to find out exactly what was happening inside a few flames. Experiments were conducted on a specially constructed furnace 6 ft. 6 in. square by 21 ft. long. First performance and combustion-mechanism trials were made with liquid fuels. The second performance trials were burner trials and the third series was concerned with comparison of oil and coke-oven gas used in different proportions.

Purpose and Practical Consequences of the Trials. Flame Radiation Research Joint Committee. (192–198). The radiation characteristics of heavy oil flames from five burners of the fluid-atomized central-fuel-jet type were studied as functions of the atomizing agent, quality, type, and the fuel input rate. Results are given in the form of curves. The differences between the radiation curves of the different burners are real but less significant than the effects of the other variables. Increase of jet momentum reduces the flame radiation all along the flame, because it reduces the flame emissivity. The use of air as an atomizing agent gave for the same jet momentum aconsiderably higher radiation in the early part of the flame than steam. The trials indicate the possibility of producing a burner which will give the same jet momentum with appreciably less steam.

A Classification of Oil-Burner Types. G. J. Gollin. (198–200). The characteristics of pressure jet and blast burners are noted. Burners used in the trials are listed.

Droplet Size Measurements on Various Steel Furnace Oil Burners. J. R. Joyce. (200–203). The size distribution of droplets from four different oil burners of steam and air atomizing type were measured by the wax method. The fineness of atomization was not markedly affected by the rate of fuel flow, but was sensitive to the quantity of atomizing air. The performance was not materially affected by the condition of the nose. The test procedure and results are presented.

The Efficiency of Momentum Production by Fluid-Atomizing Burners. R. D. Collins, G. H. Mayer, and M. P. Newby. (203–208). The momentum producing efficiencies of five burners were determined experimentally. The results are presented and theory given. Efficiencies with which the best burners operate are of the order of 75% with steam and 85% with air. Savings up to 45% in the steam used in a given flame are theoretically possible if a perfectly efficient burner can be devised.

Control of the Independent Variables and Supplies to the Experimental Furnace. G. W. Van Stein Callenfels and G. H. Mayer. (209–210). A survey is given of the improvements incorporated in the Ymuiden furnace after the 1949 trials, the main advances being the restriction of the amount of infiltrating air, and a better distribution of the combustion air. The control was then such that any given conditions could be maintained or reproduced very accurately. A steady-state heat balance of the furnace is presented.

Description of Trials and Results. R. Mayorcas and M. Rivière. (211–224). Details are given of the design and planning of the trials, the techniques of measurements on the flames, and the method of working out results. Also presented are tables of input variables applied to the burners and graphs showing the effects of the variables on several important parameters, such as the radiation and emissivity of the flames and the temperatures of the surrounding walls.

Conditions for the Stable Burning of Carbon in an Air Stream. D. B. Spalding. (*J. Inst. Fuel*, 1953, **26**, Dec., 289–294). A mathematical treatment of the factors affecting the burning of a carbon surface to CO and to CO and CO_2 is given, and some conclusions are drawn.—D. L. C. P.

The Problems of Furnace Control. L. Walter. (*Steel Processing*, 1953, **39**, Sept., 450–454, 469; Oct., 521–525). Fundamentals of automatic control are briefly outlined, and existing methods and techniques for controlling furnace pressures, draughts, fuel supplies, and combustion rates are described. Many schematic diagrams illustrate the methods discussed.—P. M. C.

Combustion and the Chain Grate Stoker. (*Babcock and Wilcox Ltd., Pamphlet No.* 1446/1, 1954). Elementary principles of coal burning and their application in the practice of boiler house operation are described.—V. G.

New Aspects of Natural-Convection Heat Transfer. S. Ostrach. (*Trans. Amer. Soc. Mech. Eng.*, 1953, **75**, Oct., 1287–1290). An analysis of the natural convection phenomena shows that the compression work and frictional heating, depending on the magnitude of a new parameter, may be of consequence in this type of heat transfer. Consideration of the specific case of natural convection flow between two parallel plates at constant wall temperature indicates that the velocity and temperature distributions, and hence the heat transfer, are altered appreciably by consideration of frictional heating.

REFRACTORY MATERIALS

Thermal Decomposition of Dolomite. R. Meldan and R. H. S. Robertson. (*Nature*, 1953, **172,** Nov. 28, 998–999). A study of two dolomites by differential thermal analysis, X-rays, and the electron microscope is reported. The work confirms that calcite crystallizes as the magnesium oxide leaves the dolomite lattice and becomes more perfect in crystal habit as heating is continued.—A. G.

Microscopical Examination of Burnt Dolomite. G. Trömel. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 449–456). In order to recognize the properties of burnt dolomite which affect the life of refractory linings made therefrom, it is necessary to know the microscopic relationships between the known chemical constituents. The structures of the most important types of burnt dolomite have been examined. The influence of alumina, iron oxide, and silica on the development of the structure has been assessed by burning samples of raw dolomite of various compositions at 1600°, 1700° and 1800° C. Even small variations in composition change the structure very markedly ; great differences are therefore found in burnt lumpy dolomite. In order to prepare a uniform sinter it is necessary to grind the raw dolomite very finely and to adjust its composition by suitable additions before burning.—J. P.

Refractories—Their Physical Properties and Behaviour. R. A. Witschey. (*Canad. Metals*, 1953, **16,** Sept., 24–26). A short discussion of a number of standard tests used to measure the physical properties of refractories is presented. The behaviour of refractories under working conditions, is briefly considered.—B. G. B.

Shrinkage in Refractory Insulating Materials. J. F. Clements and J. Vyse. (*Trans. Brit. Ceramic Soc.*, 1953, **52,** Sept., 497–511). The effect of prolonging the reheat test on insulating refractories beyond the normal 2-hr. period was studied. A 2-hr. test gives no indication of the total shrinkage latent in the brick at a given temperature, nor does it place the bricks in the order into which they would fall, as regards shrinkage, over a long period of time. An attempt was made to link the initial contraction temperature with the temperature limit of volume stability. Only a rough relationship was found. The shrinkage of the heated face of an insulating brick forming part of a furnace wall does not follow the rules applying to a block of the same material heated under soaking conditions, as in the normal reheat test.

Development of a Super Quality Semisilica Brick. D. F. Stock. (*Indust. Heating*, 1953, **20,** Oct., 2067–2070). An improved semi-silica brick is obtained by the use of a low-alkali clay (0·1% compared with 0·4–1%) introduced as coarse grained calcines. The density and porosity are the same as for other semi-silica bricks. In the standard A.S.T.M. load test the new brick showed a subsidence of 1% after 1½ hr. at 2640° F. as compared with the normal 6%.—R. W. B.

Some Considerations in the Classification of Fire-Clay Brick. W. S. Debenham and G. R. Eusner. (*Bull. Amer. Ceram. Soc.*, 1953, **32,** Aug., 272–276). A comprehensive study of the characteristics of a substantial majority of the available brands (in the U.S.A.) of high-duty and super-duty brick is presented, and the need is pointed out for a simple classification system which is properly related to service requirements. A numerical rating system based on refractoriness, strength, compactness, and spalling is proposed.—J. R. P.

Permeability and Some Other Properties of a Variety of Refractory Materials. II. G. B. Massengale, L. E. Mong, and R. A. Heindle. (*J. Amer. Ceram. Soc.*, 1953, **36,** Aug., 273–278). For abstract of Part I *see J. Iron Steel Inst.*, 1954, **176,** Jan., 104. The results of the permeability tests, and data on moduli of elasticity, porosity, and bulk density are presented and discussed.—R. A. R.

Greater Accuracy in the Phase Diagram of the System Al_2O_3–SiO_2. P. P. Budnikov, S. G. Tresvyatskii, and V. I. Kushakovskii. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93,** (2), 281–283). [In Russian]. A thermal investigation (using tungsten–molybdenum thermocouples) of the system Al_2O_3–SiO_2 in the high-alumina region is reported. The fusion temperature of mullite was determined as 1900 ± 20° C. X-ray and microscope studies of fused mullite indicated that it does not decompose during fusion. The fusion temperatures of mixtures are : 15% SiO_2 + 85% Al_2O_3, 1960 ± 20° C., and 22·7% SiO_2 + 77·3% Al_2O_3, 1870 ± 20° C.—V. G.

Refractories in the Service of Industry. D. Dixon. (*Refract. J.*, 1953, **29,** June, 246–248, 255 ; July, 297–300 ; Aug., 333–336 ; Sept., 378–381 ; Oct., 426–429 ; Nov., 470–472). This series of articles surveys the field of refractories and picks out significant developments which have taken place since 1945. Many aspects are touched upon from raw materials and manufacturing methods to the properties of the products and present trends in the type of material used for various purposes. Special attention is paid to iron and steelworks requirements, the enamelling industry, and to the use of refractories in coke ovens and combustion chambers.—D. L. C. P.

Refractories 1950-1953. A. E. Dodd. (*J. Inst. Fuel*, 1953, **26,** Dec., 312–317). The review has specific sections on the low-alumina silica brick, the all-basic steel furnace, the use of carbon refractories in the blast-furnace, high temperature heat insulation, and special refractories.—D. L. C. P.

The Bottom Lining of Basic-Bessemer Converters. R. Gregoire and A. Decker. (*Rev. Univ. Min.*, 1953, **9,** Dec., 831–834). A laboratory study of the effect of the carbon content of dolomite bricks on their rate of erosion by high-FeO slags has been made. A high carbon content in the bricks increases their resistance to slag attack.—B. G. B.

Contribution to the Study of Dolomite Refractories for Basic-Bessemer Converters. P. Metz. (*Rev. Univ. Min.*, 1953, **9,** Dec., 809–831 : *Rev. Tech. Luxembourg*, 1953, **45,** Oct.-Dec., 248–268). A comprehensive account of research work carried out in the laboratory and on field trials, to investigate the performance of dolomite refractories for basic-Bessemer furnaces is given. Among the subjects studied are the rate of wear of the refractories in service, the influence of the carbon content of the bricks on their performance, and the influence of the conditions of firing the bricks during manufacture on their performance. Details of modifications made to a plant for manufacturing dolomite bricks which enabled bricks of superior quality to be produced, are given.—B. G. B.

Techniques in the Installation of Castable Refractories. E. C. Petrie. (*Indust. Heating*, 1953, **20,** Oct., 2049–2056). Techniques recommended are the use of clean cool water, clean tools, rapid mixing and casting, avoidance of heavy tamping and vibration during setting, and drying at not over 230° F. for 12 hr. after which it can be raised at 100–150° F./hr. to the working temperature of the unit.—R. W. B.

Side-Blow Converter Refractories. R. A. Clark. (*Amer. Foundryman*, 1953, **24,** Oct., 34–39). The author considers the lining of side-blown converters with acid refractories and describes in detail the preparation, construction and preheating of a rammed monolithic lining of ganister. The effects of ramming, preheating, blowing rate, and metal composition on refractory wear are discussed and the repair of the linings briefly described.—B. C. W.

Vermiculite as a Fuel Saver. K. W. Cowling. (*Refract. J.*, 1953, **9,** Sept., 371–377). The article deals with the history, occurrence, constitution, behaviour on heating, and properties of exfoliated vermiculite, and its use as a heat insulator.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Foreign Metallic Recuperators, Tower Type. W. Trinks. (*Indust. Heating*, 1953, **20,** Oct., 1958–1966). **Recuperators for Blast-Furnaces.** W. Trinks. (*Blast Furn. Steel Plant*, 1953, **41,** Dec., 1437–1438). The design and capabilities of Heiligenstaedt, Austeel-Escher, and Schack recuperators are reviewed. The Escher as compared with the Heiligenstaedt has provision for expansion and part of the outer shell is bare to avoid overheating. Axial and parallel flow have enabled airpreheats of 1200° F. to be obtained. In the Schack, helical and counter flow is employed for flue gas temperatures up to 2700° F. For large recuperators the heating surface is subdivided into tubes to resist thermal stresses more readily ; their success depends on the tube packing.—R. W. B.

Reduction of Iron Ore without Melting, in a Rotary Furnace. B. Kalling and F. Johansson. (*J. Iron Steel Inst.*, 1954, **177,** May, 76–85). This paper deals with a new method for reducing iron ores, without melting, in a rotating furnace. Tests have been carried out in a semi-scale furnace at the Domnarfvet Steelworks in Sweden. The construction of the furnace and the results so far obtained are described. Several ores have been tried as well as different kinds of fuel. A furnace of special type has been constructed for desulphurization of the sponge iron produced. The possibilities of the process for steelmaking are discussed.

Construction and Operation of Carbon Lining in Gary's No. 10 Blast Furnace. J. M. Walsh, jun. (*Blast Furn. Steel Plant*, 1953, **41**, Dec., 1439–1450). This furnace, blown in in February 1953, has a carbon lining extending from the bottom of the hearth staves to 35 ft. above the mantle. The author discusses aspects of this furnace under five headings; Changes in furnace design, lining construction, curing the carbon, blowing in, and furnace operation. Sectional diagrams of the furnace are reproduced. The furnace performance to date has been very satisfactory.—B. G. B.

Development and Status of the Stürzelberg Process of Pig-Iron Production. H. Hofmeister and C. Herrmann. (*Demag News*, 1953, (131), 1–11). A fairly detailed description of this process, which has been working continuously since 1936, is given. Two rotating reverberatory furnaces are used, one for heating the iron-bearing material and calcining the limestone, and the other for reduction and melting. Fine ore and coke can be used and the process is not affected by the sulphur content of the raw material. It is useful for melting complex ores (*e.g.*, those containing zinc and lead), which are unsuitable for charging into the blast-furnace. The zinc and lead oxides can be profitably recovered.—B. G. B.

Low Shaft Furnaces. G. Bulle. (*Blast Furn. Steel Plant*, 1953, **41**, Dec., 1429–1433). The construction and operation of low-shaft furnaces for the smelting of low-grade iron ores with low-grade solid fuel or the production of ferro-alloys are reviewed. Brief details of the Klöckner-Humboldt furnace, the international low-shaft furnace near Liége, and a ferro-manganese furnace which has been in successful operation since 1951 in Germany, are given.—B. G. B.

C. F. & I. Operations: E. & G. Brooke Plant. F. Coburn. (*J. Met.*, 1953, **5**, Oct., 1338). The sintering and blast-furnace plant at the Colorado Fuel and Iron Corporation's works at Birdsboro (Pa.) are briefly described.—G. F.

Blast-Furnace Practice at Appleby-Frodingham: A Review of Recent Developments. H. S. Ayres. (*Iron Coal Trades Rev.*, 1953, **167**, Dec. 25, 1463–1469). The author reviews the modern techniques in blast-furnace operation used at the Appleby-Frodingham Steel Co. and discusses the changes made since 1929. Ore preparation methods are considered first, followed by accounts of plant mechanization, relining procedures including the use of explosives, the development of carbon refractories, and blowing procedure.—G. F.

New Skinningrove Blast-Furnace: Increasing Plant Efficiency. H. G. W. Debenham and W. H. Tubbs. (*Iron Steel*, 1953, **26**, Oct., 460–467; Nov., 507–512). Implementation of the First Development Scheme at the Skinningrove Iron Co. Ltd. has included the installation of a modern blast-furnace and full auxiliary plant. The authors describe the design and layout of the furnace and auxiliaries, and draw attention to structural and layout features of special interest.

Recording Blast-Furnace Performance Data and Operating Details. R. Kingston. (*Iron Coal Trades Rev.*, 1953, **167**, Dec. 11, 1347–1351). The value to the operator of maintaining comprehensive records of blast-furnace operation and performance is stressed and the factors to be taken into account are outlined. Four main units to the recording system are suggested, each being discussed in turn, and an example is given of a tabulation containing the relevant matter on which to judge operating efficiency.—G. F.

Iscorians Reline Blast Furnace in Under 20 Days. (*Iscor News*, 1953, Dec., 13–17, 50–59). A day-to-day account of the relining of No. 3 blast-furnace at the Iscor Works, Pretoria, is given. The total time from blowing out to blowing in was 20 days.—V. G.

The Reduction of Iron Ores of the Pyrenees. A. Guédras. (*Métaux–Corrosion–Indust.*, 1953, **28**, Oct., 410–414). The production of iron from iron-bearing materials by natural gas, which occurs in the Pyrenees, is discussed. The design of a suitable reaction vessel is described. This consists of two vertical columns, in which gaseous reduction and preheating of the ore take place, joined to a vessel (basically an open-hearth furnace) where the smelting and refining of the reduced material occurs. Diagrams of the equipment are given. Accurate control of the iron composition, which is suitable for the production of nodular cast iron, is considered possible.

Kinetics of Low-Temperature Reduction of Iron Ores—The Reduction of Synthetic and Natural Iron Ores with Hydrogen. S. T. Rostovtsev and A. P. Em. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93**, (2), 329–334). [In Russian]. Kinetics of the low-temperature reduction of samples of (*a*) natural high-grade iron ore (Krivoi Rog), cut into slabs, (*b*) the same ore crushed and compressed into slabs, (*c*) chemically pure Fe_2O_3 heated before reaction to various temperatures, and (*d*) synthetic ores containing various gangue materials were investigated. The kinetics of reduction of finely crushed rich ore do not differ from that of chemically pure ferric oxide. At temperatures below the point of eutectoid decomposition of FeO, the reduction proceeds in three stages through the metastable ferrous oxide phase. During the reduction of ore in its natural crystalline state the kinetics of the process are different. On the curve for the dependance of reduction rate on time or degree of reduction, the signs of the existence of three separate stages of the process are absent. This apparent change in the kinetics of reduction is explained by the low adsorption capacity of the ore. Fine crushing of ore with subsequent briquetting considerably increases the velocity of reduction. The presence of gangue materials (SiO_2, Al_2O_3, and CaO) only slightly decreases the velocity of reduction without changing the character of the process.—V. G.

On the Activities of Co-existent Elements in Molten Iron. II—The Activity of Silicon in Molten Iron. K. Sanbongi and M. Ohtani. (*Tetsu to Hagane*, 1953, **7**, July, 683–687). [In Japanese]. Using concentration cells at approx. 1520° C., values were obtained for the activity of silicon in molten iron and the free-energy change of silicon solution. The binary iron–silicon solution was shown to be a semi-regular solution, obeying Henry's Law within limits. (10 references).—K.E.J.

Solid Phase Identification in Partially Reduced Iron Ore. G. Bitsianes and T. L. Joseph. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5**, Dec., 1641–1647). As a step towards better understanding of the overall process of iron ore reduction, the authors have studied the solid phases formed during reduction, using a co-ordinated sequence of macro-, micro- and X-ray examination. The reduction takes place at distinct interfaces between well-defined layers of the solid phases iron, wüstite, magnetite, and hematite.—G. F.

Exchange of Iron Between Liquid Metal and Iron Silicate Slag. G. Derge and C. E. Birchenall. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5**, Dec., 1648–1650). Using radioactive iron (Fe_{55}) as tracer, the authors have determined that the equilibrium exchange of iron between silica-saturated iron-silicate slag and liquid iron in a silica crucible follows first-order kinetics, with a rate constant of 0·006 at 1600° C.—G. F.

Manganese as an Indicator of Blast-Furnace Slag Oxidation and Desulphurizing Power. N. J. Grant, J. W. Dowding, and R. J. Murphy. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**, *J. Met.*, 1953, **5**, Nov., 1451–1454). The study of a large number of blast-furnace heats and of laboratory slag-metal tests has shown that manganese reduction is a better indicator of desulphurizing power than any common measure of slag basicity. Reversion of sulphur from slag to metal due to oxygen additions is confirmed, and maximum desulphurizing ability is not reached owing to the system's oxidation potential.—G. F.

Production of High Titanium Slag. T. Rokujo. (*Tetsu to Hagane*, 1953, **39**, July, 733–747). [In Japanese]. A review is given of the development of titaniferous magnetite smelting, and the properties and methods of production of high titanium slag. (27 references).—K. E. J.

Preparation of Metallic Iron of High Purity. G. A. Moore. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5**, Nov., 1443–1449). The author outlines methods of producing high-purity iron, listing typical analyses, and then describes a method producing an iron more pure than any previously made. The method consists of ether extraction of $FeCl_3$, reduction to $FeCl_2$, further purification, and electrolytic deposition of metallic iron which is hydrogen-annealed to remove carbon and oxygen.—G. F.

TREATMENT AND USE OF SLAG

The Influence of Granulation on the Properties of Slag Sand. W. Kramer. (*Stahl u. Eisen*, 1953, **73**, Nov. 19, 1596–1600). A single batch of blast-furnace slag was granulated in two ways; the equipment and operation are described and the action of changes in water feed are fully discussed. In one case the grains of slag sand were porous and in the other they were solid and compact. The former sand was superior as a hydraulic cement and the latter had better properties as an aggregate.—J. P.

Cement from Blast-Furnace Slag. A. Fichtner. (*Hutník* (Prague), 1953, **3**, (10), 218–222). [In Czech]. A survey is made of past and present methods of utilizing blast-furnace slag for cement manufacture. It is concluded that methods, more complex than hitherto employed, will have to be put into practice if blast-furnace slag is to become a valuable industrial raw material.—P. F.

PRODUCTION OF STEEL

Aciéres de Longwy. (*Aciers Fins Spec. Franç.*, 1953, Nov., 91–92). [In English]. The organization, plants, and products of the Société de Aciéries de Longwy are briefly described.—V. G.

C. F. & I.—Expansion Through Diversification and Dynamic Leadership. (*J. Met.*, 1953, **5**, Oct., 1308–1365). The Colorado Fuel and Iron Corp. is now the ninth largest steel producing concern in the U.S.A. controlling 14 modern industrial plants. Various branches of the Corporation's activities are described in this series of articles, abstracts of which follow :

C. F. & I.: History and Expansion. A. M. Riddle. (1310–1312).

C. F. & I. Operations: Pueblo Plant. R. Smith. (1320–1329). An account is given of the layout and operations carried out at the Corporation's Pueblo plant in Colorado, with particular reference to the recently installed seamless tube mill. Descriptions are also given of the coking plant, ore preparation plant, blast furnaces, open hearth shop, rolling mills, rod and wire mills, and water and power supplies.

C. F. & I. Operations: Buffalo Plant. A. E. Giblin. (1330–1333). The sequence of operations at the Corporation's Buffalo works is covered from the unloading of the iron ore to the blast-furnaces, open-hearth furnaces, rolling mills, and rod and wire mills. Brief descriptions of the various plants are included.

C. F. & I. Operations: Palmer–Morgan–Clinton. F. G. Lindstrom. (1334–1337). Operations at the Palmer, Morgan, and Clinten works of the Corporation are described. The wire mill at Palmer supplies wire to the Palmer rope mill, the Morgan spring mill, and to the Clinton mill which produces wire cloth, spirally woven belts, vibrator screens, and perforated metals.

C. F. & I. Operations: Claymont Plant. H. J. Davis. (1339–1341). An account is given of the layout of the Corporation's plant at Claymont, and the open-hearth shop, 160 in. and 120 in. plate mills, flanging department, and pipe mill are described.

C. F. & I. Operations: Pacific Coast Plants. K. H. Baessler. (1342–1344). The Pacific Coast Division of the Corporation operates a wire mill at South San Francisco and a weaving plant at Oakland producing a wide range of woven wire fabrics. Brief descriptions of the two plants are given.

C. F. & I. Subsidiaries: American Wire Fabrics Corp. B. L. Weaver. (1345). The Mt. Wolf plant of the American Wire Fabrics Corporation produces industrial wire fabrics of various meshes from steel, aluminium, bronze, copper, nickel, and Monel wire. A brief account of the works is given.

C. F. & I. Subsidiaries: John A. Roebling's Sons Corp. A. Neroni. (1346–1359). A detailed description is given of the processes and products of the two plants of John A. Roebling's Sons Corp. at Roebling and Trenton, New Jersey. The open-hearth plant and hot-rolling mills at Roebling are considered first and the production of steel wire is described. Cold-rolling and the production of wire rope at Trenton are dealt with and attention is given to bridge building.

C. F. & I. Plant Interrelationship. J. S. Hawley. (1360–1361). A summary is given of the products of the Corporation's main works, their inter-relationship, and the major improvements since 1945.

C. F. & I.: Transportation. W. DeBoer. (1362).

Sinter for Open Hearth Charge. E. G. Hill. (*Blast Furn. Steel Plant*, 1953, **41**, Dec., 1434–1436, 1438). The necessity to increase the open-hearth hot metal charge from 47 to 61% at the Steubenville plant of the Wheeling Steel Corp. made it essential to lower the slag volume as larger slag pots were not available. This was accomplished partly by reducing the silicon content in blast-furnace operation and partly by using a sintered ore charge in the open-hearth furnace having low silica, sulphur and phosphorus contents. Sintering of fine high-grade ores on a Dwight-Lloyd machine was carried out and details of the results obtained are given.—B. G. B.

Physically Hot Iron for the Open Hearth. D. M. Morrison. (*Indust. Heating*, 1953, **20**, Aug., 1540–1542, 1650). The different opinions as to the use of hot metal in open-hearth furnaces are considered. Open-hearth operators seem to prefer physically hot iron because of less trouble with metal mixer, less skull in ladles, and faster working heats. The desirability of making the best possible slag, not necessarily the leanest, is emphasized.—B. G. B.

Iron and Steel Making Processes Used in Sweden. S. Fornander. (*J. Iron Steel Inst.*, 1954, **177**, May, 1–12). After a historical introduction and a short account of the raw material situation, a description is given of the various processes used in Sweden for the making of pig iron, sponge iron, and ingot steel. Emphasis is laid on the characteristic features of Swedish technology compared with foreign practice, which are due mainly to Sweden's scarcity of fossil fuel and its relatively large resources of hydro-electric power.

Fuel and Its Usage. E. E. Callinan. (*Iron Steel Eng.*, 1953, **30**, Nov., 55–59). The author studies the relation which exists between oil fuels and open-hearth furnace availability. The study is limited to the methods of using fuels and is not extended to fuel chemistry. Brief references are made to supply systems, the presence of sulphur, burners, atomizing agents, and maintenance of furnace and burners.—M. D. J. B.

Furnace Design and Brickwork. H. C. Paxson. (*Iron Steel Eng.*, 1953, **30**, Nov., 66–70). The author describes developments in furnace design with particular reference to reduction in refractory wear. Hearth, front wall, back wall, furnace ends, fantails, and checker design are examined.

Furnace Rebuilding. W. H. Shure. (*Iron Steel Eng.*, 1953, **30**, Nov., 61–65). The author discusses means of increasing open-hearth furnace availability through better rebuilding programmes. Planning and scheduling of operations are described and the need for good supervision and adequate manpower is stressed. The latest equipment used in rebuilding is discussed.—M. D. J. B.

Basic Hearth Construction and Maintenance. G. R. Bashforth. (*Brit. Steelmaker*, 1953, **19**, Dec., 704–711). The author discusses improvements in methods of basic hearth construction and maintenance made in the past 30 years. After mentioning some causes of hearth failure, factors affecting fettling time are reviewed, and taphole construction and hearth shape are considered. The relative merits of rammed and fritted hearths, and of magnesite and dolomite hearths, are discussed. Finally, the relatively new graphitized dolomite hearth and sub-hearth construction are considered.—G. F.

Comparison of American and German Basic Open-Hearth Furnaces. A. Ristow. (*Stahl u. Eisen*, 1953, **73**, Nov. 19, 1574–1583). On the basis of data published in the period 1948–1952, American and German open-hearth furnaces are compared with respect to raw materials, productivity, heat supplies and consumption, and hourly output.—J. P.

Experience in Fast Melting Gained at the Třinec Steelworks. J. Pszczolka. (*Hutník* (Prague), 1953, **3**, (10), 223–225). [In Czech]. An account is given of the method of high-speed melting employed in a basic 130-ton open-hearth furnace, having an ordinary silica roof, a semi-automatic Zimmerman-Jansen reversing valve and employing coke-oven gas plus blast-furnace-gas as fuel. Charging, control of the furnace, and the organization of the work are described, and a detailed log listing the order of the operations is given. The heat required 9 hr. 20 min.—P. F.

New Pouring Ladles for the Steelworks of the Koninklijke Nederlandse Staalfabrieken N.V. H. G. Linterman. (*Lastechn.*, 1953, **19**, Nov., 214–220). [In Dutch]. With the greatly increased yearly output to 300,000 tons at the Ymuiden blast-furnaces, it became necessary to design much larger pouring ladles, and an all-welded type was constructed ; this is described. The weight of the unlined ladle was reduced to 30 tons thus giving a ratio of 1 : 7 when empty and filled.

Some Observations of Slag-Metal Relations in the Acid Open Hearth Steel Furnace. G. R. Fitterer. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5**, Dec., 1634–1640). The composition of acid open-hearth slags, and particularly the variation in iron and manganese oxides during refining, are reviewed, and a procedure currently used to control the refining reactions is described and partially explained by phase-diagram considerations. The ionic nature of the

slags is discussed. the suggestion being made that a series of complex silicate ions is formed by combination of silica and the oxide ion, which is furnished additively by the basic oxides FeO, MnO, and CaO.—G. F.

Behaviour of Sulphur in Basic Open-Hearth Furnace. I—The Behaviour of Sulphur in the Furnace Atmosphere. II—The Behaviour of Sulphur in the Molten Phase. I. Murata, G. Maeda, T. Uno, and E. Homma. (*Tetsu to Hagane*, 1953, **39**, June, 582–587 ; July, 677–682). [In Japanese]. Furnace studies showed that sulphur pick-up from the atmosphere was greatest during charging, and depended on scrap quality. The equilibrium was examined theoretically. During melting and refining the sulphur in the atmosphere appeared not to influence the bath, and to be in equilibrium with that in the slag. The influences of slag basicity and fluidity, and sulphur in the lime and iron ore are examined. Desulphurization proceeds mainly by transfer between the bath and the slag. Change in sulphur content in the ladle is also discussed.

Diffusion of Calcium Ion in Liquid Slag. Helen Towers, M. Paris, and J. Chipman. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **6**, Nov., 1455–1458). The authors have explored the possibilities of tracer techniques to measure diffusion coefficients in liquid slags and have established the basis of a technique. Values of the coefficient for calcium ion in a 40%-CaO–40%-SiO_2–20%-Al_2O_3 slag are given for the range 1350–1450° C.—G. F.

Fundamental Study on the Special Steel Making (Measurement of Equilibrium between Boron and Oxygen in Liquid Steel.) T. Yagihashi and T. Sato. (*Tetsu to Hagane*, 1953, **39**, June, 575-581). [In Japanese]. Equilibrium conditions in the reaction between boron in liquid iron and H_2–H_2O gas mixtures at 1600° C. were measured, and the equilibrium constant and free energy obtained. The oxygen content was calculated, and hence the deoxidation product and free energy of the reaction between boron and oxygen in the iron were obtained. Comparisons are given with previous theoretical and experimental work. (12 references).—K. E. J.

Study of Grain Size of Steel (Difference of Grain Size between Acid and Basic Open-Hearth Furnace Steels During the Steelmaking Process). S. Maekawa and Y. Nakagawa. (*Tetsu to Hagane*, 1953, **39**, July 698–704). [In Japanese]. Basic steel displayed fine but irregular grain size, although addition of a ferrosilicon deoxidizer rendered it more homogeneous. Acid steel showed coarse but homogeneous grain size. The grain size characteristics are related to the refining reactions involved, those in the acid furnace being more slow and thorough.—K. E. J.

For Cheaper Heats . . . Budget B.T.U's. M. F. Hall. (*Steel*, 1953, **133**, Dec. 14, 130–137). The automatic and improved fuel control system on the twelve 200-ton open-hearth furnaces at the Fairfield Steelworks of U.S. Steel Co. is described, and the advantages over manual setting pointed out. Provision is made for metering producer gas or natural gas, and tar or fuel oil with only two meters.—D. L. C. P.

Can the Electric Furnace Compete with the Open Hearth? C. F. Ramseyer. (*J. Met.*, 1953, **5**, Dec., 1617–1621). The author discusses the possibilities of the electric furnace competing with the open-hearth furnace. He compares the economics of the two practices, their operating costs per ton and per furnace hour, and total heat times. He concludes that the deciding factor will be whether or not the electric furnace can handle hot metal charges economically.—G. F.

New 10-Ton Electric Arc Furnace at the Works of Thos. Firth & John Brown Limited. (*Iron Coal Trades Rev.*, 1954, **168**, Jan. 1, 29–31, 33). A description is given of the new 10-ton E.F.C.O.–Heroult arc furnace installed at the Atlas Works of Thos. Firth and John Brown Ltd. for the production of stainless and special alloy steels. The furnace is 11½ ft. in dia. and of the swing-roof type.—G. F.

Large High-Frequency Furnaces: New 12-Ton Steel-Melting Units at A.B. Bofors, Sweden. (*Iron Coal Trades Rev.*, 1953, **167**, Dec. 18, 1429–1430). Two 12-ton acid-lined H.F. furnaces have recently been installed by AB Bofors in Sweden for the production of high-quality carbon steels. Brief descriptions are given of the furnace construction, motor generator and condenser units, control gear, and auxiliary machines.—G. F.

Experiences Gained in the Utilization of Stainless Steel Scrap in the Oxygen-Blown Arc Furnace. A. Danihelka. (*Hutnické Listy*, 1953, **8**, (8), 411–418). [In Czech]. Experiments relating to the decarburization of chromium steel heats in arc furnaces with oxygen are reported. Decarburization can be attained, but in general the temperature is also raised sufficiently to endanger the furnace lining, and carbon begins to be taken up by the melt from the lining and from the electrodes. Until the problem of suitable linings is solved high working temperatures must be prevented by reducing the oxygen-rate and by eliminating as far as possible the non-ferrous elements in the charge, so as to prevent undesirable heating of the charge by their oxidation. Chromium steels with carbon contents of about 0·12% could then be produced by oxygen blowing without undue loss of chromium.—P. F.

Progress in Theories of Steelmaking Reaction and Their Contribution to Practical Operation. Y. Matsushita. (*Tetsu to Hagane*, 1953, **39**, June, 635–654). [In Japanese]. A survey is made of the contributions to steelmaking practice arising from the understanding of slag–metal reactions. The model of a molten slag should conform with microscopical evidence. The importance of interface reactions is stressed. A new factor "B_r" is proposed. to replace slag basicity, to describe deoxidation, desulphurization, dephosphorization and other reactions. (60 references).—K. E. J.

The Manufacture of Silicon Capped Steel. A. Lami. (Amer. Iron Steel Inst.: *Indust. Heating*, 1953, **20**, Sept., 1742–1754, 1849). A practice of effectively capping moulds by the use of ferrosilicon is described. The advantages of capped steels over fully rimmed steel are discussed. The disadvantages of mechanically capping steel are explained.—B. G. B.

Change in Ingot Shape During Zone Melting. W. G. Pfann. (*Trans. Amer. Inst., Min. Met. Eng.*, 1953, **197**: *J. Met.*, 1953, **5**, Nov., 1441–1442). During zone-melting, the ingot becomes slightly tapered. The author shows that this is due to the volume change on melting and can be prevented by inclining the ingot at a critical angle. The mechanism of matter transport is similar to that of solute transport by a molten zone, and is described by a similar equation.—G. F.

The Status of Continuous Casting at Allegheny Ludlum. W. B. Pierce. (Amer. Iron Steel Inst. : *Blast Furn. Steel Plant*, 1953, **41**, Nov., 1301–1306). *See J. Iron Steel Inst.*, 1954, **176**, Mar., 312.

PRODUCTION OF FERRO-ALLOYS

Conservation of Manganese. (*Min. J.*, 1953, **241**, Oct., 16, 440–441). A short summary of a number of official reports on the subject of manganese conservation is presented and a number of possible methods of economy in the use of the manganese resources of the world, is discussed.—B. G. B.

Extraction of Tungsten, Chromium and Vanadium from High-Speed Steel Wastes with an Héroult Furnace. S. Sakai. (*Tetsu to Hagane*, 1953, **39**, June, 595–601). [In Japanese]. By addition of oxidizing slags to specially prepared carbide slags, and by direct reduction of scale and scrap from grinding in coke powder and ferrosilicon, extraction rates of 90%, 80%, and 20% were obtained for tungsten, chromium, and vanadium respectively. Equilibrium studies showed an optimum working range of 1600–1650° C. for the first two metals. (10 references).—K. E. J.

FOUNDRY PRACTICE

Foundry Progress in the First Half of 1953. P. A. Heller. (*Stahl u. Eisen*, 1954, **74**, Jan. 1, 35–39 ; Jan. 14, 106–111). The literature is reviewed. (98 references).—R. A. R.

Ultra-Pure Metals Produced By Zone-Melting Technique. E. E. Schumacher. (*J. Met.*, 1953, **5**, Nov., 1428–1429). The author briefly discusses the theory of the zone-melting technique for the production of ultra-pure metals and examines its future possibilities. A series of narrow molten zones is moved slowly along an ingot, and the different solubilities of the impurities in the liquid and solid phases causes progressive refining with each successive zone.—G. F.

A Plant for Melting and Casting Under High Vacuum for Research Work. O. Winkler. (*Giesserei, Technisch-Wissenschaftliche Beihefte*, 1952, Sept., 435–437). Equipment for H.F. melting and casting up to 5 kg. of metal in high vacuum is described, and the whole process of carrying out such an operation is followed in detail. A time–pressure diagram of the melting and casting of steel shows clearly the degassing that takes place first on heating and then rapidly on melting.

Vacuum Melting Excludes Inclusions. F. G. Stroke. (*Steel*, 1953, **133**, Dec. 14, 140–141). Examples are given of instances in which ' clean ' vacuum-melted steels of accurately

controlled composition have been or may be used to advantage. Vacuum-cast chromium–carbon alloy steel is favoured for high quality anti-friction bearings. Improved fatigue properties are reported which may prove to be of value for heavily loaded bearings.—D. L. C. P.

Further Works' Results with Coreless Mains-Frequency Crucible Induction Furnaces for Grey Iron Castings. F. Deutz. (*Giesserei*, 1953, **40,** Nov. 12, 609–614). Results obtained with 1½-ton, 3-ton and 6-ton coreless mains-frequency crucible induction furnaces are compared from the point of view of the current used and the efficiency. Losses of carbon and silicon are shown to be negligible. Costs of each type of furnace are given in detail and the economics discussed.

A Thought on Metal Melting. J. E. Rigby. (*Australian Found. Trade J.*, 1953, **4,** Aug., 25–27). The urgent need to reduce production costs in the castings industry is discussed. The use of sand moulding machines is advocated, and the saving to be made by improved melting methods are emphasized. The Sklenar oil-fired reverberatory furnace is described in detail. Capacities from 30 lb. to 5 tons are available, the furnaces using about 2 gall. of heavy fuel oil per 100 lb. of iron.—P. M. C.

Production of Sound Castings by Controlled Rate of Heat Transfer. C. A. Parlanti. (*Trans. Inst. Eng. Ship. Scotland*, 1952–53, **96,** 246–264). The importance of heat transfer control in the production of castings is discussed and the use of anodized aluminium moulds for chill casting is described.

Heat Transfer by Means of Free Convection in Metal Melts. H. Klein. (*Z. Metallkunde*, 1953, **44,** Oct., 450–456). Heat transfer in a fluid metallic melt was calculated for free convection to a vertical plate by means of an approximation formula derived by Eckert from Prandl's boundary layer theory. The results show that an explanation of the heat transfer at the solid-liquid phase boundary is possible without making new assumptions. To test the validity of the boundary layer theory under these conditions experimental verification was obtained by suitable measurements.—L. D. H.

The Boudouard Equilibrium and Its Importance for Shaft Furnaces, Especially the Cupola. H. Schiffers. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct., (12), 561–570). The dynamic combustion reactions that regulate the Boudouard, Gumz, and Preen equilibria, respectively, are first considered. The manner in which the height of the air zone and the reduction zone in the furnace depends on the specific surface of the fuel and the air velocity is then discussed. Variations in the height of the furnace and the choice of air velocity enable the required burning rate to be achieved.

The Use of Calcium Carbide in Cupola Melting. S. F. Carter and R. Carlson. (International Acetylene Assoc. : *Canad. Metals*, 1953, **16,** Aug., 30–32 ; Sept., 28–32). The difficulties encountered in cupola operation when an iron with a high carbon content or low sulphur content is required are discussed. A method using calcium carbide in lump form which is added to the charge in a basic cupola, is described. This has enabled iron with a relatively high sulphur content to be melted in the cupola to give a low sulphur iron. The final carbon contents were also much higher than that normally obtained on comparable charges. Details of tests are given and the mechanism of the process is considered briefly. Similar results, but with less reduction in sulphur, have been obtained in acid cupola practice.—B. G. B.

Quicker and Easier Charge Calculations. H. Pieper. (*Giesserei*, 1953, **40,** Oct. 29, 595–597). Examples are given of the use of a nomogram to facilitate calculating cupola charges.—R. A. R.

Selection, Moulding, and Cupola Melting of Medium Duty Cast Irons. F. C. Eager. (Inst. Australian Foundrymen : *Australian Found. Trade J.*, 1953, **5,** Sept., 11–16, 23, 25, 26). The author first describes the effect of section size on tensile strength, and proceeds to discuss chemical compositions and the effect of individual elements on hardness and other mechanical properties. Moulding techniques are described, details being given about sands, pouring temperatures, gates, risers, and pouring speeds. Cupola melting practice is dealt with finally. Wind volume, charge size, type of coke, bed height, fluxes, alloy addition, and tapping are all considered in some detail. (12 references).—P. M. C.

New Methods of Melting Cast Iron Borings in the Cupola. S. H. Chrobok. (*Giesserei*, 1953, **40,** Nov. 26, 634–637). Crofts new charging method is described in detail and the economic aspects are considered, these being especially favourable for high alloy castings. The rate of charging can be readily varied. Results indicate that oxidation losses are normal and the tapping temperature is unaffected. Analyses and properties are tabulated. The production of pigs from charges of 100% borings is described.—R. J. W.

Experience in the Production of High-Silicon Iron Castings. M. Pachowski. (*Przeglad Odlewnictwa*, 1953, **3,** (11), 322–328). [In Polish]. The properties of high-silicon irons are outlined and brief details of crucible melting and the production of these castings are given. Control of production and some possible defects are discussed.—V. G.

The So-Called " Nuclei " in Spheroidal Graphite. A. Wittmoser. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct. (12), 571–585). This is a review describing work on spheroidal graphite. Evidence and arguments are presented for and against the existence of so-called ' nuclei '. (64 references).—R. J. W.

Elevator Furnaces at Gloucester Foundry for Blackheart Malleable. P. F. Hancock. (*Found. Trade J.*, 1953, **95,** Dec. 10, 733–736). A description is given of the Birlec Ltd. electrical furnaces used for annealing blackheart malleable iron castings at the Gloucester Foundry Ltd. The installation consists of a low temperature and a high temperature furnace placed side by side with movable bogie hearths. The method of operation is outlined.—B. C. W.

The Control of the Quality of Material in the Malleable Iron Foundry. V. Unger. (*Giesserei*, 1953, **40,** Dec. 10, 668–672). The measurement of the strength properties of test bars is the main method for assessing the quality. Charge preparation and subsequent thermal treated are considered separately. The effect of carbon on the texture is dealt with in detail. Recommendations are made for furnace repairs, furnace lining, and melting.—B. J. W.

Latest U.S.S.R. Achievements in the Production of Inoculated Malleable Cast Iron. J. Raczka. (*Przeglad Odlewnictwa*, 1953, **3,** (11), 316–322). [In Polish]. A brief review is presented of Russian work on : Inoculation of malleable cast iron with aluminium and titanium ; neutralization of stabilizing effect of chromium by additions of aluminium ; modified heat-treatment of inoculated iron ; and the influence of chemical composition, speed of cooling, temperature, and duration of heat-treatment on the properties of spheroidal pearlitic malleable iron.—V. G.

Contribution to the Mechanism of Graphite Crystallization in Iron. E. Feil. (*Giesserei*, 1953, **40,** Nov. 26, 629–634). A brief review is made of the literature. Observations are described on the formation of graphite in near-eutectic and hypereutectic irons, and on the formation of flake and spheroidal graphite. The symmetry of the latter is considered. A chemical investigation on kish graphite is also described. The progress of crystallization during solidification is illustrated. The primary and secondary stages of carbon crystallization and the solidified residue are designated C1, C2, and C3 respectively, and the effect of the silicon content on these three phases is considered. (14 references).

Effect of Alloying Elements on Graphitization of a White Iron Containing Small Per Cent of Chromium. N. Tsutsumi. (*Tetsu to Hagane*, 1953, **39,** June, 620–626). [In Japanese]. The effects of 21 metallic and non-metallic deoxidizing elements were investigated. It was concluded that no strong graphitizing agent was available to neutralize the retarding effect on graphitization of chromium (approx. 0·15%) in blackheart iron. (10 references).—K. E. J.

Electric Steel Foundries Control Dust Emissions in Los Angeles Area. O. E. Erickson. (*J. Met.*, 1953, **5,** Dec., 1625–1626). The necessity for dust control in the Los Angeles area has promoted the use in electric steel foundries of various types of dust collectors including wet collectors, electrostatic precipitators, and bag filters. The most successful type, considering initial and operating costs together with efficiency, is the tube-type bag filter with Orlon bags and proper shaking and control devices.—G. F.

Composition Control of Steel Castings Improved by New Furnace Sampling Methods. V. E. Belusko. (*J. Met.*, 1953, **5,** Nov., 1430–1432). The introduction of rapid methods of sampling and estimating carbon in basic electric furnace practice at the Electric Steel Foundry Co. has led to an average saving in time of 20 min. per heat and to improved composition control. On lower carbon heats a Brinell test block is cast and its hardness related to carbon content from a previously constructed graph ; with higher carbon, a thin rod

sample is drawn by suction pump into a Pyrex tube for combustion analysis.—G. F.

Rönnskär's Production and Development in Recent Years. O. Herneryd. (*Blad Berg. Vänner*, 1953, **30**, (3), 389–409). [In Swedish]. In this review of the operations of Bolidens Gruvaktiebolag at Rönnskär, near Skellefteå, it is stated that in 1951 an 8-ton electric steel furnace (2500 kVA.) was installed for the continuous sand-casting of 35–50 mm. balls for grinding. Their hardness is 50–60 Rockwell C. In 1953 production would probably be 3000 tons.—R. A. R.

Side Blow-Steel Converter Practice. J. R. Robinson. (*Australian Found. Trade J.*, 1953, **4**, Aug., 9–15). Following a brief historical survey, present trends and typical side-blown converter design are discussed. The composition of the charge is outlined, and a table of heat values is given showing the exo- or endothermic nature of the reactions occurring during a blowing cycle. The blowing cycle is fully described, and some observation on steel quality and accuracy of control during the process are recorded. (10 references).—P. M. C.

Steel Casting and Cement Sand Moulds. J. Lombardi. (*Fonderia Ital.*, 1953, **2**, Sept., 571–576). [In Italian]. The author briefly reviews the materials which can be used for moulding, and describes in detail the technique of adding Portland cement to agglomerate foundry sands. The raw materials, mixture requirements, cohesion, permeability, humidity, and the plant and equipment required to obtain the best results are described.—M. D. J. B.

Compound Casting of Cast Iron or Steel and Aluminium (Al-Fin Method). G. Gürtler. (*Giesserei, Technisch-Wissenschaftliche Beihefte*, 1952, Sept., 429–433). The different possible compound casting methods are described, especially that developed by the Fairchild Engine and Airplane Corp., New York, (the Al-Fin method). Micrographs are shown of the texture of the connecting layer between steel or cast iron and an aluminium alloy. The process is one of dipping the iron-base part into a bath of the aluminium alloy. A successful bonding depends mainly on the temperature, time, and composition of the bath. The method of working and the properties of these complex castings are described. Examples of applications of this technique are illustrated.—R. J. W.

Concerning Rejects Due to Cracks, Shrinkage Cavities and Gas Occlusions in the Mass Production of Cast Steel Solid Wheel Discs in Semi-Chilled Moulds. A. Pack. (*Giesserei*, 1953, **40**, Oct. 15, 557–567). The type of casting and the moulds used for making cast steel solid wheel discs, are first described in detail together with the statistical method used. The principal causes of rejecting a percentage of the castings were (*a*) cracks, (*b*) shrinkage cavities, and (*c*) gas occlusions. These are dealt with separately, and the methods for eliminating them considered.—R. J. W.

Trend Towards Automation in Automatic Weighing and Bulk Materials Handling. I. H. Richardson. (*Mech. Eng.*, 1953, **75**, Nov., 865–870). A machine in operation at the General Electric Foundry, U.S.A. is described which automatically delivers a 2000-lb. batch of correctly proportioned sand, plus additions, to the mullers every minute.—D. H.

New Moulding Sand Preparation Machine, Known as "Junkerath" Mixer. W. Geil. (*Demag News*, 1953, (132), 5–9). A new machine for preparing moulding sands employs the principle of alternately kneading and spinning the material. The machine is continuous in operation and has been used successfully on natural and synthetic moulding sands.

Reactions on the Surface of Moulds. K. Roesch. (*Giesserei*, 1953, **40**, Oct. 29, 581–585). Chemical and physical reactions at the surface between the mould sand and the cast material are intensified by a higher casting temperature, and a thicker wall. Moulds must be permeable to gas to avoid blowholes in the surface of the steel. The development of these gases during an actual casting operation is followed and the apparatus described. Gas measurements from mould materials in a laboratory furnace are also described.—R. J. W.

Flow Properties of Foundry Sand: Significance of the Bond Energy Ratio. J. Gittus. (*Iron Steel*, 1953, **26**, Oct., 475–478; Nov., 501–506; Dec., 551–553). In considering the 'flowability' of foundry sands, the author has used laboratory methods to determine the flow properties of a series of synthetic sand mixes. It is shown theoretically that certain tests give results related to the 'bond energy ratio'. the practical implications of which are discussed. The results of a number of empirical tests are governed by this ratio and such tests, particularly the shatter and loose flow tests, can conveniently be used for routine control purposes.—G. F.

Synthetic Moulding Sands. Z. Wertz. (*Przeglad Odlewnictwa*, 1953, **3**, (9), 257–263). [In Polish]. The preparation, properties, uses, and methods of recovery of synthetic moulding sands are outlined.—V. G.

Testing Foundry Sands by D.I.N. and A.S.F. Methods. G. Somigli. (*Fonderia Ital.*, 1953, **2**, Sept., 577–583). [In Italian]. The author gives a detailed account of the German and American Foundrymen's Society standard methods of testing foundry sands and concludes that the two methods could be unified and standardized. The design of test samples and methods of preparation, testing techniques, and apparatus are described.—M. D. J. B.

Binding Property of Moulding Sand. J. Kashima and M. Mutaguchi. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 43–45). [In English]. A polarographic method is put forward as being more satisfactory than colorimetric methods for determining clay content of moulding sands, relations between sand and organic binders, and degrees of deterioration.

Moulding Sand Binders. T. Makiguchi. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 39–42). [In English]. The binding properties of clay for sand moulds were investigated under reduced pressure. Removal of water of crystallization is accelerated. Binding strength is increased and permeability is satisfactory. Moulds can be made at lower temperatures than previously used.—K. E. J.

A Contribution to the Microscopical Examination of Core Binders. F. Roll. (*Fonderie*, 1953, June, 3480–3487). The apparatus and optical techniques available for the microscopical examination of core binders are briefly described. The material is dispersed in a suitable liquid and, by using different reagents, it is possible to analyse the core binder both qualitatively and semi-quantitatively. Examples are given of the application of the techniques.—B. C. W.

Drying Foundry Moulds *in situ*. G. Ulmer and M. Decrop. (*Fonderie*, 1953, May, 3431–3443). The theoretical and practical aspects of the drying of large moulds by portable heaters are considered in detail. Coke, gas, electric, and infrared portable heaters are described and some results presented of practical tests carried out with them. Particular attention is devoted to the economics of each system.—B. C. W.

Mould-Oven Trolleys. (*Fonderie*, 1953, Apr., 3403–3407). The various types of car for transporting moulds to and from ovens are described and their serviceability and efficiency discussed.—B. C. W.

Asbestos in Foundry Operations. W. M. Halliday. (*Canad. Metals*, 1953, **16**, Oct., 28–32). The use of asbestos for making modifications to moulds without the necessity for altering the design of the pattern is discussed, and a number of examples of this use are given.—B. G. B.

Patternmaking for the Repetition Foundry. R. R. Shaw. (*Found. Trade J.*, 1953, **95**, Nov. 26, 645–649). Methods of making patternplates are described in detail. The examples considered include patterns of castings where both halves are identical, patterns with an irregular parting line, shell patternplates for heavy castings, and cast matchplates.—B. C. W.

The Stressing and Construction of Wood Patterns. F. Lamm. (*Giesserei*, 1953, **40**, Dec. 24, 691–693). The stresses to which the body of the pattern and the core box are likely to be subjected are explained and divided into three groups: (*a*) Those for repeated use; (*b*) those for occasional use; and (*c*) those to be used only once. The dimensions and the method of making these types of pattern are described. The construction of dissectable patterns and pattern parts are treated separately.—R. J. W.

Gating to Control Pouring Rate and Its Effect on the Casting. F. J. McDonald. (*Amer. Foundryman*, 1953, **24**, Dec., 36–41). Results are presented of an investigation into the effects of sprue cups, sprue posts, ladle height, cross-section runner, and skim cores on the pouring rate and on casting defects. It is concluded that, providing the metal flow is fast enough to avoid mis-runs, the slower the pouring rate the fewer the casting defects. Skim cores were found not to remove slag directly but, by reducing the metal velocity, to allow more slag to adhere to the top of the runner. Good control over pouring rate can be achieved by varying sprue-post diameter or by using runner chokes. To avoid variation in casting thickness the ladle height should be controlled.

Relation of Riser Range and Feeder Adequacy. W. S. Pellini. (*Amer. Foundryman*, 1953, **24,** Nov., 58–66 ; Dec., 62–71). The solidification of castings with particular reference to the size and positioning of risers is discussed. The rate of growth of a solid skin on the walls of a casting is determined by the different rates of heat extraction at the various positions, which in turn are governed by the ratio of casting volume to the heat-extracting sand area (V/SA). If the castings are of the same shape the solidification times are proportional to $(V/SA)^2$ but where a change of shape is involved empirical corrections are required. Using the (V/SA) relationship, it is possible to calculate the minimum size of riser necessary to give the same solidification time as a simple casting but corrections are necessary with complex castings. The relationship between feed channels and shrinkage (both centreline and gross shrinkage) is discussed and thermal analysis data are presented to show the thermal gradients necessary to feed bar and plate castings. The maximum distance in sound bar and plate castings that can be fed by risers is very small and data are given to illustrate the effect on this of both end chills and chills placed between risers. The solidification and feeding of joined plate castings is also discussed. The application of the data obtained with the plain carbon steel castings to castings of other metals is briefly considered.—B. C. W.

Old Castings as Patterns. (*Found. Trade J.*, 1953, **95,** Nov. 5, 567). A brief description is given of the modifications necessary to enable an old casting to be used as a pattern for a replacement.—B. C. W.

Templates in Patternmaking. F. H. Wakeham. (*Found. Trade J.*, 1953, **95,** Oct. 1, 431). The use of templates in gauging carved and turned patterns is briefly described.

What Is a Good Pattern? W. Siekert. (*Foundry*, 1953, **81,** Sept., 132–133). The vital stages in the construction of a large and complicated pattern are outlined and the necessity for co-operation between designer and patternmaker is stressed.—B. C. W.

Plastic Patterns Offer Advantages in Investment Casting. R. S. Banister. (*Foundry*, 1953, **81,** Sept., 120–124). On production jobs to be made by investment casting, polystyrene plastic patterns made by injection moulding are an economic replacement for wax patterns. Plastic patterns are dimensionally stable and give smoother, stronger joints which decrease the number of patterns lost in the dip coat and investing operations. Although plastic is more difficult to burn out than wax, satisfactory oven cycles can readily be arranged.—B. C. W.

Experiments with Different Types of Feeder. B. Thyberg. (*Gjuteriet*, 1953, **43,** Oct., 175–181). [In Swedish]. During comparative tests on a cylindrical malleable iron casting, in which the feeder was an extension of the casting, it was noted that Washburn cores had little effect on metal flow. Exothermic powder (iron oxide, aluminium powder and a binder) placed on top of the feeders to give additional heat proved excellent but extremely expensive. Examples are given of small castings made using a new type of pouring-cup feeder in which a hexagonal strainer core floats to the surface when the mould is filled, the surface of the feeder being kept warm by the core.—G. G. K.

Experiences in the Exothermic Feeding of Grey-Iron Castings. J. Grice. (Inst. British Foundrymen : *Found. Trade J.*, 1953, **95,** Dec. 17, 749–759). Results are presented of experiments into the use of exothermic feeding compounds in the casting of flywheels and hydraulic cylinders. With exothermic sleeves, porosity under the feeder head was avoided with the flywheel castings and the yield of metal was increased. The hydraulic cylinders still showed some internal porosity and a breaker core was substituted for the exothermic sleeve.—B. C. W.

Anti-Feeding and Piping [Feeding and Anti-Piping] Compounds. H. Thaler. (*Australian Found. Trade J.*, 1953, **4,** Aug., 21, 23). A brief general appraisal is given of the advantages to be gained by the use of feeding and anti-piping compounds. Delayed freezing of ingots with these compounds allows the concentration of major segregation immediately under the base of the primary pipe cavity. Local analyses at 16 points in a 4-ton, 0·68% carbon steel ingot are tabulated.

The Problems of Manual Mould Preparation. M. Arrighetti. (*Fond. Ital.*, 1953, **2,** Nov., 657–660). The author attempts to rationalize the problems of manual foundry casting and groups the various operations under the headings of types of mould preparation, position of mould, mould construction, and method of pouring. A description is given of the casting technique adopted for a 2-ton iron casting.—M. D. J. B.

Mass Production of Lathe Beds by the Core Moulding Process. K. Schaaf. (*Giesserei*, 1953, **40,** Nov. 12, 620–622). The method of core moulding, especially for the manufacture of lathe beds, is described and the economic advantages pointed out. The costs of this process are compared directly with the ordinary moulding method.—R. J. W.

Evaluating Moulding Machines. W. Gesell. (*Giesserei*, 1953, **40,** Dec. 24, 682–684). A moulding machine can be evaluated from the following considerations : (*a*) Economics, (*b*) efficiency, (*c*) machine operation, and (*d*) the moulding technique. Each of these is considered separately. The economic factor is the most important. The efficiency of the machine will depend on numerous factors such as the type of sand used, the pattern, and the casting.—R. J. W.

How Effective Core Storage Helps. (*Canad. Metals*, 1953, **16,** Oct., 32–36). A brief account of a system for storing cores used in a large foundry, is given. The cores are stored in racks which can be moved by fork lift trucks and are stacked in tiers of two.—B. G. B.

Catalytic Combustion Control in Core-Baking Ovens. R. J. Ruff. (*Amer. Foundryman*, 1953, **24,** Dec., 42–44). To prevent explosive concentrations of core oil vapours from accumulating in a core oven, a platinized-mesh catalytic unit can be fitted to the oven exhaust to oxidize all the combustible gases. With a thermostat on the exhaust side of the filter the oven burners can be controlled so that dangerous fume concentrations never occur. By measuring the temperature of the exhaust gases before and after passing through the catalytic unit it is possible to obtain information as to the drying cycle of the cores. Under certain circumstance it might be possible economically to recover the heat generated by the catalytic unit.—B. C. W.

Foundry Stoves, with and without Recirculation of Gases. R. Bernotti. (*Fonderia Italiana*, 1953, **2,** Sept., 585–593). [In Italian]. The author describes the operation of foundry stoves dividing the functions into drying, vaporizing the moisture, and ventilation. Different types of stoves are considered together with a range of fuels and the fuel efficiencies obtainable. Heat losses and heat balances are discussed and the relative merits of stoves with and without gas recirculation are considered.—M. D. J. B.

The Use of Chill Casting Methods in the Iron Foundry. W. Wien. (*Giesserei*, 1953, **40,** Nov. 26, 644–645). The use of chill moulds for producing runs of castings is considered. The manufacture of the main cylinder for a hydraulic brake system and the preparation of sand cores are described.

Centrifugical Steel Moulds. (*Aciérs Fins Spec. Franç.*, 1953, Nov., 56–58). Mechanical properties and chemical composition of steel used for centrifugical moulds together with methods of their manufacture and maintainance are outlined.

Centrifugal Casting of Alloy Steels. (*Canad. Metals*, 1953, **16,** Oct., 24–26). A short account of a new steel casting foundry of Sheepbridge Engineering (Canada) Ltd., at Guelph, Ontario, is given. Centrifugal methods are used to produce alloy steel castings for aeroplanes.—B. G. B.

F. L. C. B. Shell-Moulding Equipment. (*Found. Trade J.*, 1953, **95,** Dec. 10, 730–732). **Progress in Shell Moulding.** (*Iron Coal Trades Rev.*, 1954, **168,** Jan. 8, 93–95). An illustrated summary of the construction and method of operation of a new design of shell-moulding equipment manufactured by Fairbairn, Lawson, Combe Barbour Ltd. of Leeds is given. The equipment is compact and is manually operated with a production of 40 half shells per hour.—B. C. W.

Application of Shell Moulding to Steel Castings. C. Hand, and P. R. Beeley. (*Found. Trade J.*, 1953, **95,** Dec. 17, 745–747, 759). This is a survey of the types of shell-moulded steel castings produced at Sheepbridge Steel Castings Ltd., Sutton-in-Ashfield. Castings are being made in both austenitic and plain carbon steels with much thinner sections than are possible with normal moulding methods, and with much improved surface finish and accuracy of dimensions.

Shell Moulding. (*Australian Machinery*, 1953, **6,** Sept., 25–27). The production of castings to close tolerances by the shell moulding process is briefly described. Dry silica sand mixed with finely powdered phenolformaldehyde resin is used to form a shell $\frac{1}{8}$ in. thick round a hot metal pattern. The melted resin binds the shell, (which is made in separate halves) together, and subsequent baking produces a hard

mould ready for casting. Several automatic shell moulding machines, suitable for mass production, are now on the market. The Polygram Mark IV machine is illustrated. Close tolerances, fine surface finish and detail, less metal wastage, and reduced labour and finish cleaning costs are features of the new process.—P. M. C.

Coleman–Wallwork Shell Mould Making Machine. (*Machinery*, 1953, **83**, Oct. 9, 722–724). A new design of shell mould making machine for which certain important advantages are claimed has been introduced by Coleman-Wallwork Co. Ltd., Stotfold. The machine can be built at low cost, and is arranged to produce fully cured shells from two pattern plates alternately. The machine is designed for use with existing single sided or double sided match plates.—M. A. K.

A New Lost-Wax Precision Casting Foundry. (*Machinery*, 1953, **83**, Sept. 11, 507–514). **Lost-Wax Precision Casting.** (*Machinery*, 1953, **83**, Oct. 2, 651–656). The article describes the preparation of the moulds and casting, the curing ovens, melting furnaces, and a large sand reclamation plant installed at the precision casting foundry of the B.S.A. Co., Ltd. at Redditch, where the lost-wax process is operated.—M. A. K.

Shell Moulding of Cylinder Castings. A. Emmerson. (*Found. Trade J.*, 1953, **95**, Dec. 3, 687–696). A detailed account is given of the shell moulding practice used by Macmillan Foundries Ltd., Watford, for grey iron castings weighing up to 200 lb. Although at present the shell-moulded castings cost as much or more than those produced by conventional methods they have a much better surface finish and are cast to closer dimensional tolerances. The quality of the castings is higher due to the uniform rate of cooling and the absence of chilling.—B. C. W.

Mechanized Shell-Moulding Plant. H. K. McGavock. (*Found. Trade J.*, 1953, **95**, Nov. 12, 591–593). After gaining experience with an experimental shell moulding plant, the Lynchburg Foundry Co., Lynchburg, Virginia, has decided to install a full-scale production foundry with an output of 100 tons of finished castings every 24 hr. The proposed layout of the foundry, which is to be fully mechanized, is described in detail.—B. C. W.

Ceramic Moulds for the Foundry. T. A. Dickinson. (*Found. Trade J.*, 1953, **95**, Sept. 10, 333–335). The author reviews a number of methods at present being developed in the U.S.A. for casting ferrous and non-ferrous alloys in permanent ceramic moulds. The materials used for making the moulds include glass, porcelain, enamelled steel, clay products, and castable refractory mixtures of plaster.—B. C. W.

Part Needs Determine Best Casting Method. D. von Ludwig. (*Iron Age*, 1953, **172**, Sept. 3, 128–132). Plastic, wax and mercury investment casting and the shell moulding method are described and compared. Production by investment casting is usually for less than 10,000 units, shell moulding for more than 1000 units. Shell mouldings are said to be competitive for parts weighing more than 1 lb.—A. M. F.

Precision Casting with Green Sand. (*Amer. Foundryman*, 1953, **24**, Sept., 34–38). A detailed description of foundry practice at the La Crosse (Wis.) Works of Allis-Chalmers Mfg. Co., which produces inoculated grey iron and alloy iron castings for agricultural machinery. The foundry specializes in casting to close tolerances to reduce or avoid subsequent machining.—B. C. W.

Simplified Moulding. (*Found. Trade J.*, 1953, **95**, Nov. 26, 661–664). The advantages of co-operation between the design department and the moulding shop are stressed. Examples are given to show how redesigning the patterns for a **V**-belt pulley and a geared winding-drum casting not only enabled the moulds to be made by semi-skilled production methods but also gave a higher output of sound castings.

Productivity Ideas in the Jobbing Foundry. (*Machinist*, 1953, **97**, Sept. 26, 1604–1608 : *Mech. Handling*, 1953, **40**, Oct., 498–502). The article describes how improved efficiency was achieved in the jobbing foundry of Rice and Co., Ltd. after a member of the firm returned from a productivity team's visit to the U.S.A.—M. A. K.

The Use of Industrial Trucks in Foundries. (*J. d'Informations techniques des Industries de la Fonderie*, 1953, Sept., 1–4). The usefulness of stack trucks and pallets in improving the handling of materials is shown.—A. D. H.

Project of a Foundry for Medium Sized Castings. R. Monticolo. (*Fonderia Ital.*, 1953, **2**, Oct., 625–628). [In Italian]. The article describes an ideal layout for a fully mechanized foundry for medium sized castings. Plan views, elevations, and photographs of small-scale models of the buildings are given.—M. D. J. B.

Planning a System for Materials Handling. K. F. Lange. (*Amer. Foundryman*, 1953, **24**, Nov., 42–47). A discussion is given of the problems involved in handling : (*a*) The raw materials for the cupola, moulding department, and core room ; and (*b*) the final cores, moulds, and castings. A comparison is made of the various handling methods used in foundries.—B. C. W.

High-Speed Control with Automatic Sand System. (*Amer. Foundryman*, 1953, **24**, Nov., 36–39). A description is given of the sand circulation and control system in use at the Kelsey-Hayes Wheel Co.'s foundry in Detroit. The system handles up to 240 tons/hr. of sand, and the mixers are fully automatic with integrated control mechanisms that (1) operate the sand ploughs above the storage bins, (2) add water to replace that lost by evaporation, (3) measure moisture content and add water for tempering, and (4) measure and add bonding material. The shake-out of moulds and return of sand is automatic and the whole system is interlocked in case any belt or elevator stops.—B. C. W.

Investigation on Transport in a Grey Iron Foundry as a Prelude to Mechanization. K. W. Grimm. (*Giesserei*, 1953, **40**, Dec. 10, 653–657). The handling problem for the foundry under consideration is first stated. The conveying work required from various parts of the foundry is then shown by pictorial diagrams and the concealed work and the time involved in mould making is considered. A careful time-study comparison is made between the conveying work necessary before and after mechanization. The economic advantages of the latter are considered and a scheme for a mechanized foundry is suggested and discussed.—R. J. W.

Organic Fillers Seal Defects in Metal Products. H. Thielsch. (*Iron Age*, 1953, **172**, Oct. 15, 118–121). Two groups of organic fillers, one for sealing micro-defects and the other for large defects are used for salvaging rejected cast and welded parts. These materials, being thermosetting, harden fully and do not soften when reheated. Repaired areas can be machined by conventional methods, sand-blasted, cleaned, painted or lacquered.—A. M. E.

Vacuum Impregnation Makes Porosity-Free Castings. J. H. Leary. (*Mat. Methods*, 1953, **38**, Sept., 91–93). Micro-voids and porosity in metal castings can be corrected by impregnation. The castings are placed in a chamber which is then evacuated to draw the air from the voids. A liquid (polyester, or phenol-formaldehyde) is admitted to the chamber until the parts are covered. Pressure is then applied to force it into the innermost pores. A subsequent curing treatment is usually carried out, and depends on the type of liquid used. Details of the process and its capabilities and applications are discussed.—P. M. C.

The Determination of the Surface Tension of Different Molten Cast Irons. K. Grütter and B. Marinček. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct., 587–592). The method of measurement of surface tension of molten cast iron is by measuring the depression in the level of the molten liquid in two capillaries of different diameters. The mathematics for the determination of surface tension, making allowance for the meniscus, is followed, and the method of performing the experiment described. Tables are supplied to assist calculations and a numerical example is worked out. The surface tension of ordinary cast iron is of the order of 800–1100 dynes/cm. If spheroidal graphite is present this may be increased by 50%. The marked dependence of surface tension on the sulphur content was established, but dependence on temperature did not agree with previously published work.—R. J. W.

The Mechanism of Thermal Crack Formation in Cast Alloys. W. Patterson. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct., 597–605). Factors influencing the formation of thermal cracks are first considered and an experiment designed to form thermal cracks is described. Such cracks are characteristic of alloys with a large solidification range. The crystallization front in equilibrium with the mould in solid solution alloys is considered in the light of equilibrium diagrams and melting curves. Eutectic alloys are discussed separately. Thermal cracks are distinguished from tensile cracks.—R. J. W.

The Mechanism of Residual-Stress Formation in Sand Castings. R. N. Parkins and A. Cowan. (*J. Inst. Metals*, 1953, **82**, Sept., 1–8). Experiments carried out with cast

iron show that the residual stresses in sand castings may result from : (*a*) Temperature differences set up during cooling : (*b*) phase transformations in the alloy ; and (*c*) resistance to construction offered by the sand. The magnitude of the contribution by each of these is considered.—B. G. B.

The Carbon Dioxide Solidification Method in the Foundry. W. Schumacher. (*Giesserei*, 1953, **40**, Dec. 24, 678–681). The theoretical basis of a new mould and core manufacturing method is first described, together with the chemical reactions that take place. The process employs a special binder containing water-glass which is hardened by blowing in CO_2. Some examples of the application of this method are described. The economics of the method are carefully considered. Appreciable savings per casting can be effected over the methods used hitherto. No detrimental effect of the method on the operators was observed.—R. J. W.

Designing an Iron Foundry. D. Appleyard and S. Rosenberg. (*Found. Trade J.*, 1953, **95**, Nov. 19, 619–621). A design is presented for an iron foundry to suit the requirements of Ransomes, Sims and Jeffries, Ltd., Ipswich, which was prepared by the authors as a project in their architectural studies. The foundry is assumed to operate the shell moulding process.—B. C. W.

Once upon a Time, . . . J. B. McIntyre. (*Found. Trade J.*, 1953, **95**, Nov. 5, 561–564). The author describes a pioneer French foundry established in 1859 which made use of advanced mechanical methods for moulding and handling materials. The works had very highly developed welfare provisions for the employees and was later organized on a profit-sharing basis.—B. C. W.

Supercooling and Dendritic Freezing in Alloys. W. C. Winegard and B. Chalmers. (*Amer. Soc. Metals, 35th Annual Convention*, 1953, *Preprint No.* 16). Supercooling may result from the enrichment in solute of the liquid immediately ahead of the advancing solid-liquid interface. If the supercooled zone is small, a cellular structure will be developed; if the zone is large, dendrites will form. It is suggested that dendrites in ingot structure are produced as a result of constitutional supercooling and that the dendritic equiaxed zone in the centre of ingots is a result of nucleation in a large constitutionally supercooled region. The pasty condition sometimes found in alloys is also explained.—J. O. L.

Gas and Blowholes in the Foundry. A. Portevin. (*Fonderie*, 1953, June, 3457–3479). This is a detailed and comprehensive discussion of gases and blowholes in both ferrous and non-ferrous castings. The aspects of the problem which are considered include: (1) Solubility of gases as a function of temperature and pressure; (2) the hydrogen/copper-oxide reaction; (3) the carbon/iron-oxide reaction and the distribution of blowholes associated with killed, semi-killed, and rimming steel; (4) the effect of reduced pressure on blowhole formation; and (5) the nature of blowholes and the methods of preventing them.—B. C. W.

The Use of Statistical Methods for Metallurgical Problems in the Foundry. E. Zingg. (*Giesserei, Techniche-Wissenschaftliche Beihefte*, 1952, Sept., 409–417). The advantages of employing mathematical statistics for the solution of different foundry problems are ennumerated. The use of punched cards and punched card machines, calculating machines mathematical tables, and graph paper are described. Several examples of the practical uses of statistical methods involving hardness, phosphorus content, and various strengths of cast iron are given.—R. J. W.

Foundry Industry Looks at Apprentice Training. R. G. Greiner. (*Amer. Foundryman*, 1953, **24**, Dec., 50–53).

Foundry Safety Practices. (*Amer. Foundryman*, 1953, **24**, Oct., 54–60). This is an extract from the introduction to a new dust and ventilation control manual being prepared by the American Foundrymen's Society. Details are given of the toxicity and recommended maximum allowable concentrations for 21 metals and organic compounds which are used or are present in ferrous and non-ferrous foundries.—B. C. W.

A Basic Foundry Cost System. E. Paltenghi. (*Amer. Foundryman*, 1953, **24**, Oct., 62–66). A simple costing system is presented which can be applied to the operations of any type of foundry. The breakdown of costs between departments is illustrated graphically and, using imaginary figures, calculations are given to show how the cost of a casting may be obtained.—B. C. W.

HEATING FURNACES AND SOAKING PITS

Rotary Reheating Furnaces in Rolling Mills. J. Krejčí. (*Hutnické Listy*, 1953, **8**, (8), 394–400). [In Czech]. The construction and mode of operation of the circular and annular types of billet reheating furnaces are discussed. A comparison is made between the running costs and thermal efficiency of rotating and pusher furnaces, the results being in all cases in favour of the former. The construction and features of the most important parts of rotary furnaces are considered.—P. F.

Reheating of Rolled Billets by Induction. E. Langer. (*Hutnické Listy*, 1953, **8**, (9), 470–475). [In Czech]. Principles and methods of heating billets by induction are discussed. The relation between billet dimensions and optimum frequency is given and used to interpret experimental data on the induction heating of structural and carbon steel tubes and billets. The cost of induction heating is compared with that of resistance heating and of ordinary gas and oil-fired furnaces. The respective costs vary with the diameter of the tubes and billets, but resistance and induction heating are in general the cheapest.—P. F.

Shell Forging and Heat Treating. A. Q. Smith. (*Indust. Heating*, 1953, **20**, Aug., 1514–1522). The installation of gas-fired furnaces with rotary hearths for heating for forging and heat-treating is discussed. A modern conveyor and manipulator system which handles billets for hot extrusion and draw-forming of 90 mm., 105 mm., and 120 mm. shells is described.—B. G. B.

Fundamental Considerations in the Construction and Operation of 'Half-Gas' Furnaces. K. Kessels and H. Kallenbach. (*Stahl u. Eisen*, 1953, **73**, Nov. 19, 1590–1596). The development of automatic stoking has made it possible to produce a consistently good combustion gas and, as a result, "half-gas" firing is now competitive with full-gas firing. The peculiarities of the kind of furnace are discussed and some operational results on a pusher-type billet heating furnace are reported.

Performance of Ingot Heating Furnaces. S. A. Limpach and R. J. Reed. (*Steel Processing*, 1953, **39**, Aug., 392–398). Performance tests have been carried out on three bar-type ingot reheating furnaces with 9 ft. × 20 ft. hearths, heated by five natural-gas burners in the rear wall. Two of the furnaces were equipped with recuperators, and average productions, loadings, fuel consumptions, efficiencies, temperatures, and gas analyses over a continuous operating period of about six weeks are recorded. The thermal efficiences of the recuperator equipped furnaces were 11 and 11½%, whilst the third was 8½%.—P. M. C.

Instrumentation and Control of Mill Furnaces. Instruments Sub-Committee of the Plant Engineering Division. (*Brit. Iron Steel Res. Assoc.*, Sept., 1953). This 36-page booklet is in four parts which describe and discuss: (1) Measurements and controls for operation of mill furnaces; (2) examples of soaking pit and reheating furnace instrumentation systems at present in operation; (3) experiences and achievements in the use of automatic control; and (4) installation and maintenance of works instruments. A table summarizes instruments in common use and their functions.—R. A. R.

Cylindrical Chamber Furnaces: New American Equipment for Continuous Reheating of Steel Tubes. M. Lorant. (*Brit. Steelmaker*, 1953, **19**, Oct., 596–599). The author briefly describes the operation and design of a line of thirteen cylindrical chamber furnaces installed at the American National Tube Co. for heating pierced seamless tubes for rolling. Accurate temperature control is achieved by automatic temperature adjustment in each successive unit and also by regulating the transit speed of the tube sections.—G. F.

Soaking Pits: A Review of Developments and Operating Results, 1941–53. R. W. Berry. (*Iron Coal Trades Rev.*, 1953, **167**, Oct. 16, 887–892). The author reviews technical data which have been published in the past 12 years on the various types of soaking pit used in the steel industry, comparing their operating results and discussing their advantages and disadvantages. Other factors dealt with are soaking-pit capacity, fuel consumption, track time, heating rules, and maintenance.—G. F.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Methods for the Study and Control of the Heat-Treatment of Steels. L. Jeníček and B. Šesták. (*Hutnické Listy*, 1953, **8**, (10), 512–521). [In Czech]. A survey is made of existing

equipment and of recently produced Czechoslovak instruments for the study of changes in the physical states of steels during heat-treatment. Optical pyrometers and their applications, dilatometers for the study of phase-changes, magnetic flux meters, magnetic balances, electronic equipment for the study of austenite decomposition, instruments for the direct measurement of cooling rates of quenched bodies are considered.

Spectrographic Detection of Surface Carburization and Decarburization. W. Liedtke. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 465–467). The difficulties of the conventional spectrographic determination of carbon in steel are contrasted with the advantages of the method for investigating carbon distribution. A method, in which the specimen is moved mechanically under the counter-electrode, has been worked out and proved in practice. Its accuracy is illustrated by means of a carbon penetration curve.—J. P.

Cast Refractories Lower Heat Treat Furnace Costs. T. F. Keegan. (*Iron Age*, 1953, **172**, Oct. 22, 113–115). The construction of two heat-treating furnaces 23 ft. long, 5 ft. wide and 7 ft. high inside is described. The side walls were cast in full length units 27 in. high and 9 in. thick of Litecast 50. Elimination of brick construction substantially reduces the overall cost and construction time, gives better balanced operation, low heat loss, and high output. Operating at 1250° F. six days per week, there is, after eight months, sign of flaking, cracking or spalling. It is suggested that repairs will be easy.—A. M. F.

In-Plant Heat Treatment Saves $3,000 Per Year. R. W. Blosser. (*Steel Processing*, 1953, **39**, Sept., 465–468). The modernization of the heat-treatment department of the Harris Div., Harris-Seybold Co., Cleveland, Ohio, is described. A wide range of printing press components require carburizing, hardening, cyaniding, normalizing, tempering, and bend forming. By installing modern salt baths and gas-fired furnaces the Company is now able to treat all its products on the spot and show a great saving on previous heat-treatment costs.—P. M. C.

Review of Russian Practice Reveals Rail Steel Production Methods. C. A. Zapffe. (*J. Met.*, 1953, **5**, Dec., 1627–1628). The author briefly reviews a recent Russian book on the heat-treatment of rails, with particular reference to ' flaking ' and hair-line cracking. A theory of the formation of hair-line cracks is put forward, suggesting the production of entrapped methane.—G. F.

The Production of Railway and Road Vehicle Springs. (*Machinery*, 1953, **83**, Oct. 2, 666–670). Methods of producing the heavy springs manufactured by The Tempered Spring Co. Ltd., Sheffield are described,. It is shown how circular and square section springs up to 2¼ in., are coiled and tested. The process known as " scragging " which improves the properties of the spring in prolonged use is discussed.—M. A. K.

Heat-Treating Facilities Provide Versatility, Rigid Control. W. G. Patton. (*Iron Age*, 1953, **172**, Oct. 29, 106–108). A carburizing and hardening treatment of camshafts up to 50 in. long and weighing 22 lb. is described. Carbon content of the case is held between 0·90 and 1·00%. The heat-treatment furnace has a large capacity, reducing heating time to 15 min. to reach 1460° F. Quenching in a press is used to prevent distortion.—A. M. F.

Heat Treating Gears to Meet Rigid Requirements. R. Spagnola. (*Mat. Methods*, 1953, **38**, Aug., 102–103). The case-hardening procedure for helicopter transmission gears is described. The gears are made in steels A.I.S.I. 9310 (C 0·1%, Ni 3·25%, Cr 1·25%) or 3310 (C 0·1%, Ni 3·5%, Cr 1·5%) and carburized at 1700° F. in Leeds and Northrup Homocarb furnaces, using Homocarb fluid as the source of carbon supply. After quenching and tempering, the carburized areas have a hardness of Rockwell C 60–64, and the cores C 36–40.—P. M. C.

Heat-Treatment of Gear Wheels by the Ac_1-Method. F. Pobořil. (*Hutnické Listy*, 1953, **8**, (9), 450–453). [In Czech]. The method consists of heating gear wheels in a salt bath in such a way that the teeth are just above the Ac_1 point, while the body of the wheel remains ferritic. On quenching at 200° C. in oil a hard fine-grained, structure is obtained in the surface zones. The composition of the steels used was 0·7–0·9% C, 0·2–1·1% Mn, 0·2–0·4% Si, 0·0–0·5% Ni, and 0·6–1·2% Cr. Their performance was found to be superior to that of similar wheels made by conventional case-hardening processes.—P. F.

Heat-Treating Turbine Discs for Jet Engines at Wyman-Gordon Company. (*Indust. Heating*, 1953, **20**, Oct., 1902–1928). Details of the production practice for Westinghouse Disalloy and Allegheny Ludlum A286 (24–28% Ni, 12–16% Cr, 1·3·5% Mo, 1·5–2·25% Ti) are given. Rotary hearth furnaces are employed for forging, direct-fired furnaces for high temperature treatment, and radiant tube furnaces for the ageing treatment. Automatic control is practiced throughout. The heat-treatment cycles to give a Brinell hardness of 248–321 are given.—R. W. B.

Pack Carburizing Aspects and Developments. J. E. Hyler. (*Steel Processing*, 1953, **39**, July, 335–339, 349 ; Aug., 386–389, 406 ; Sept., 459–462, 475). Developments in carburizing compounds are discussed. The uses of catalysts or energizers, the importance of moisture content, handling, screening, cleaning, and re-using are dealt with in some detail. Carburizing pots and boxes, and the importance of material, size, and shape are discussed. Some aspects of container covers and cooling procedures are outlined, and box, pusher, and rotary retort type carburizing furnaces are described and illustrated. Some observations on carburization rate, the effect of time and temperature, and local carburization are made.—P. M. C.

Specialized Flame Hardening at National Supply Co. (*Steel Processing*, 1953, **39**, Oct., 529, 531, 532). The principles of flame hardening are very briefly outlined, and the use of natural gas with oxygen as the heating medium is described.

Oxy-Acetylene Flame Hardening. A. F. Chouinard. (*Canad. Metals*, 1953, **16**, Oct., 40–44), A short account of the basic principles and of the methods used for oxy-acetylene flame hardening of steel, is given.—B. G. B.

Tooling for Induction Heating. D. Warburton-Brown. (*Machinist*, 1953, **97**, Sept. 12, 1513–1519). The article deals in detail with the problem of feeding the work to the high-frequency induction heater. Various types of fundamental mechanisms which can be used to form the basis of handling equipment for a large variety of components are discussed.

Surface Hardening of Steel by High-Frequency Induction Heating. G. Perronne. (*Chaleur et Ind.*, 1953, **34**, Oct., 279–290). The principles of the method and the electric, thermal and metallurgical aspects are considered. The relationships between specific power (normally between 0·5 and 3 kW./sq. cm. of surface) penetration, and time of treatment are discussed. The equipment necessary is described and results of the method are compared with those obtained by cementation hardening. Its many advantages are stressed and applications to various machine and tool parts are listed.—A. G.

The Deep Hardening of Steel. F. van Wijk. (*Metalen*, 1953, **8**, Nov. 30, 401–406). [In Dutch]. The author discusses hardenability, quenching severity, and size of the quenched port, as these three factors govern the depth of hardening in steel. He stresses the importance of having a good method of predicting hardness values and cites Lamont's method as an example. The Jominy test is also discussed.

Nitriding Tool Steels. O. Moravek. (*Hutník* (Prague), 1953, **3**, (10), 228–229). [In Czech]. The principles, applications, and effects of nitriding are discussed in relation to several types of machine tool components. The relations between nitriding time, temperature, dimensions of component, thickness of nitrided layer, and hardness of the surface are considered.—P. F.

Production Normalizing of Steel Forgings at Allison Engine Division. (*Indust. Heating*, 1953, **20**, Nov., 2164–2170). Three Hagan furnaces are employed for a throughput of 96,000 lb./24 hr. There is two-zone control of the electric resistance elements in the first section. The second section is water jacketed and the third refractory lined. In two of the furnaces there are heating elements in the third section to enable tempering to be effected.—M. A. K.

Molten Salts for the Wire Industry. F. R. Morral and F. A. Schaufelberger. (*Wire and Wire Products*, 1953, **28**, Sept., 889–893, 921–923). Investigations of the decarburization of steel in salt baths are reported. The effects of alkalinity and of gases, particularly of water vapour, were studied. Water vapour is a possible decarburizing agent, and its dependence on age of bath and presence of rectifiers is examined. The vapour can be extracted by nitrogen and by CO. Caustic soda and soda ash are not by themselves decarburizing agents.

New Helicopter Spars Hardened in 30 Foot Long Salt Baths. (*Indust. Heating*, 1953, **20**, Nov., 2184–2186). The process consists essentially of preheating the cold worked 90-lb. spar by suspension just above a 330-kW. high temperature Ajax salt bath furnace ; immersion in the salt, and transference to a low temperature 150-kW. salt bath.—M. A. K.

Hardening of Metals. J. L. Meijering. (*Philips Tech. Rev.*, 1953, **14,** Jan., 203–211). The hardness of metals, and influencing factors such as crystal structure, foreign atoms in the lattice, and the presence of foreign molecules or groups of atoms are discussed. Methods of hardening, cold working, precipitation, and internal oxidation are reviewed. The last mentioned, developed by Philips, involves the internal oxidation of a component of an alloy by heating in (for example) air. (17 references).—P. M. C.

The Low-Temperature Relief of Stresses in Pressure Vessels. T. W. Greene. (*Lastechn.*, 1953, **19,** Nov., 222–228). [In Dutch]. Stresses can be relieved at temperatures between 180 and 200° C. by applying controlled heat to both sides of the weld with two 6 in. oxy-acetylene burners each placed 5 in. away from the weld centre. The burners should advance at a speed from 9 to 24 in./min. depending on the plate thickness, and followed at 6–8 in. by a stream of water. Stress data before and after this treatment are presented and compared.—F. R. H.

FORGING, STAMPING, DRAWING AND PRESSING

Producing Worlds Largest Steel Forgings at Bethlehem Steel Co. (*Indust. Heating*, 1953, **20,** Sept., 1680–1686). The manufacturing techniques used for the production of steel forgings 110 ft. long and 145 tons in weight for use in the construction of a die forging press are described. A number of photographs of the operation are given. The initial ingot weighed 275 tons and five forging treatments were applied.

Forged Tools: Craftsmanship at Wm. Hunt & Sons, The Brades, Ltd. (*Iron Steel*, 1953, **26,** Dec., 545–550). The firm of Wm. Hunt and Sons, The Brades, Ltd., is an example of the efficient combination of craftsmanship, old plant, modern tooling methods and modern metallurgical practice, with some modern layout and plant. The layout of the works is outlined and brief descriptions are given of the various products and methods of production.—G. F.

Tolerances in Drop Forging. O. Kienzle. (International Mech. Eng. Congress : *Metal Treat. and Drop Forg.*, 1953, **20,** Oct., 441–446). Permissible tolerances of drop forging operations are discussed and classified into groups, (*i.e.*, required accuracies for subsequent processes). The effect on tolerances of the accuracy of the die impression, the die wear during forging, inadequate matching of the dies, and inaccuracies and clearances between the trip and its guides are discussed.

Forging and Rolling of Gear Wheels. F. Drastík. (*Hutnické Listy*, 1953, **8,** (8), 400–405). [In Czech]. A survey is made of methods of producing gear wheels by forging, pressing, and rolling. Manufacture of smaller bevel wheels by hot forming is possible, the technique is not, however, applicable to large wheels. Pressing methods could be improved by decreasing the contact period between the die and the hot metal, and by making the process automatic. Rolling appears to be more promising than forging or pressing, in particular in view of resent Russian experience in this field.

Continuous Production of Improved Gautier Rail Anchors at Mid-West Forging and Manufacturing Co. (*Indust. Heating*, 1953, **20,** Nov., 2174–2180, 2330). Bars are heated in a pusher furnace fired at both ends, the control of heating being effected by varying the draught at the outlets along the furnace wall. After automatic forging and oil quenching the anchors enter the tempering furnace at 200° F. This has two zone heating and 75% of the waste gases are recirculated.

Producing Precision Forgings on a de Roll Semi-Automatic Machine. (*Machinery*, 1953, **83,** Aug. 21, 339–346). In the de Roll machine, forging is carried out by the swaging action of three equally spaced horizontal hammers which are rapidly reciprocated by eccentric shafts and strike the heated billet in unison as the latter is rotated and fed vertically through the hammer box in the base of the machine. The direction of feed for forging may be either upwards or downwards and is selected according to the nature of the work. Since forging is carried out by striking a large number of relatively light blows, the machine is of low weight in relation to its capacity, and no special foundations are required.—J. R. P.

Properly Selected Press Brake Does Work of Two Machines. J. M. Matthewan. (*Machinist*, 1953, **97,** Oct. 17, 1738–1739). The economics of selecting and operating a combined press and brake for general purpose metalworking, together with a proposed method of increasing production are described.

Press Brake Forming as a Production Tool. L. F. Spencer. (*Steel Processing*, 1953, **39,** Sept., 441–449, 468, 469). The advantages of the press brake in flexibility of performance, simplification of tool design, and low cost of tooling are described and illustrated by reference to several typical blanking, bending, punching, beading, and drawing operations. Long components with uniform sections formed by bending are ideal for this method of production. Progressive operations can also be carried out on a single machine by fitting different tools along the length of the brake.—P. M. C.

Accurate Blank Layout Aids the Diemaker. S. R. Cope. (*Machinist*, 1953, **97,** Oct. 3, 1662–1665). Accurate methods of computing blank diameters are discussed with particular reference to the graphical method of determining both blank diameters for draw and trimming diameters. Sheet metal terminology with regard to drawing properties is given.

The Hot Pressing of Metals. H. K. Barton. (*Machinery*, 1953, **83,** Aug. 7, 263–268). The introduction deals with materials amenable to hot pressing. Consideration is then given to the action of the percussion press, the crank press, and the effect of incorrect weights of billets. Five types of die are described, and the choice of these for particular applications is given, special consideration being given to the flow of the metal. The application of hot pressing dies fitted with cores is described.—J. R. P.

Horizontal Presses Designed to Eliminate " Lost Motion " in the Production of Cartridge Cases. (*Machinery*, 1953, **83,** July 31, 204–205). A novel design of press wherein both directions of the stroke are utilized has enabled an American firm to reduce substantially the time required for the production of 90-mm. cartridge cases. A brief description of the plant, its operation and advantages is given.—J. R. P.

Combinations Among Machining and Press Operations. F. Strasser. (*Steel Processing*, 1953, **39,** Sept., 455–458). The advantages to be gained under certain conditions by substituting a pressing operation for a machining operation, (and *vice-versa*), in a production process involving several operations, are discussed. Examples are quoted in which piercing has replaced drilling, and blanking has replaced turning.

The Buffalo Stamping Plant of Ford Motor Company. H. C. Hood. (*Steel Processing*, 1953, **39,** Oct., 495–500). This plant was opened in 1950. Automatic control is extensively employed, and 96 presses in 17 lines produce 2400 tons of motor-car body panels daily. Photographs of the main items of interest, and details of the operations are given.—P. M. C.

Modern Pipe Fabrication Shop. (*Indust. Gas*, 1953, **17,** Oct., 4–12). Details are given of the new pipe-bending shop at the works of C. A. Parsons and Co. Ltd., Pipes of any steel can be handled in sizes up to 12 in. bore and wall thickness of 1¼ in. Brief mention is made of the sand drying and pipe filling sections, the furnaces, and pipe bending machines.

Modern Trends in the Manufacture and Use of Cold Upsetting Tools. J. Billigmann. (*Draht, Engl. Ed.*, 1953, Dec., 13–18). Tool life is discussed with reference to the influence of tool design, tool steel, and its heat-treatment ; the use of cemented carbides is also thoroughly treated.—J. G. W.

Stresses, Construction, Manufacture, and Life of Cold-Flow Pressing of Steel. K. Sieber. (*Draht., Engl. Ed.*, 1953, Mar., 32–37). Tools for cold extrusion are dealt with. It is shown how load capacity of dies can be increased by single and double reinforcement. Wear of dies and tests with small batches to obtain data to improve die performance are discussed. So far no success with tungsten carbide tools has been recorded.—J. G. W.

Which Metal Form—Spun or Drawn? J. W. Lengbridge. (*Mat. Methods*, 1953, **38,** Aug., 87–91). An appraisal is made of the relative costs, dimensional accuracies, and contour problems involved in both spinning and drawing metal shapes. The spinning properties of steels and non-ferrous metals and alloys are tabulated. The author concludes that both processes have advantages and limitations, the choice depending on the circumstances of the application.—P. M. C.

Stretch-Forming. (*Aircraft Prod.*, 1953, **15,** Nov., 440–442). A description of new equipment suitable for the manipulation of sections and narrow sheet is given.—B. G. B.

Follow These Principles in Dies for Shallow Shells. S. R. Cope. (*Machinist*, 1953, **97,** Oct. 10, 1704–1707). The importance of selecting correct clearances, bottom and drawing radii, and the general permissible reductions is discussed. Suggestions regarding the maximum reductions in blanks for

shells of steel, brass, aluminium, and zinc are made. Pinch trimming, and design of drawing dies and combination dies are also described.—M. A. K.

Extrusion: The Newest Metal Working Method in Industry. T. F. McCormick. (*Steel Processing*, 1953, **39**, Aug., 379–382, 398). The author outlines in very general terms the methods and plant used for the direct and indirect extrusion of metals. The many advantages and uses of extrusion in the production of intricate sections are discussed. Aluminium alloy components for the aircraft industry are the principal components dealt with.—P. M. C.

Intricate Steel Shapes Now Cold Extruded. M. W. Riley. (*Mat. Methods*, 1953, **28**, Sept., 100–101). Low-carbon steel extruded parts of intricate shape are being produced by the Mullins Manufacturing Corp. An unspecified lubricant is bonded to the steel by a phosphate coating. The accuracy and smoothness of finished forms, and the low scrap loss are quoted as big advantages. Several typical cold extruded parts are illustrated.—P. M. C.

Know Your Terminology for Drawn Shells. S. R. Cope. (*Machinist*, 1953, **97**, Sept. 26, 1610–1613). The author discusses the general principle of drawing metal and shows the eight basic types of shells which may be drawn. The types of metal used for drawing operations are given and the recommended structural composition for each is described.—M. A. K.

Deep-Drawing Properties of Sheet Steel: Fundamental Principles and Test Methods. O. E. Svahn. (*J. Iron Steel Inst.*, 1954, **177**, May, 129–142). The Research Organization of Jernkontoret has been working, through a Research Committee, on the problem of deep-drawing tests since 1945. Ten deep-drawing qualities of sheet steel were tested by a number of regular test methods for sheet material. Statistical calculations show that the classification cannot be verified between the different methods or by repeated tests with the same method. A tendency for the Erichsen tests to correspond to deep-drawing with pure elongation has been found. The basic condition of deep-drawing have been studied with five materials with very wide variations in physical and metallurgical properties. The Committee found that two test methods, approximating very closely to actual practice, merited presentation. Both are cup tests, one for deep-drawing with material sliding and the other for deep-drawing with pure elongation. The possibilities of reproducing the test values are very good, if the test properties are well defined. The Committee intends to publish its proposals in the near future in the hope of establishing an international standard test for determining the drawing quality of sheet material.

Deep Drawing Without Blankholders. F. Strasser. (*Steel Processing*, 1953, **39**, Aug., 390, 391). Two empirically determined diagrams are given, which indicate the maximum heights of round and rectangular cups drawable without blank holders for various stock thicknesses and cup diameters.

Needle Tube Production. (*Steel*, 1953, **133**, Nov. 2, 90–91). The Superior Tube Co., Norristown, Pa., turn out special tubing in 55 metal analyses. Sizes range from 0·008 in. to 0·625 in. outside dia. with some light wall products up to 2 in. in dia. The sequence of operations in producing 20 gauge hypodermic needle tubing (0·035 in. dia.) from 1·5 in. stock, is described.—D. L. C. P.

Stainless Steel Wire Drawing through Diamond Dies. W. F. G. Kerley. (*Wire Ind.*, 1953, **20**, Nov., 1095–1106, 1113). Following an historical survey of development of machines and dies with particular reference to the drawing of stainless steel wire present-day practice followed by Samuel Fox and Co. Ltd., Sheffield, is described in detail with emphasis on the manufacture, maintenance, and servicing of the diamond dies.—J. G. W.

Borax As a Lubricant in Wire Drawing. O. Peltzer. (*Stahl u. Eisen*, 1953, **73**, Oct. 22, 1424–1425). The advantages of using borax instead of lime as a lubricant carrier in wire drawing are discussed. It is better, on health grounds, as it creates less dust. It is readily soluble in water and the solution does not require stirring. One immersion of the wire is adequate. The borax coating can be dried at low temperature at a greater rate than a lime coating and the fluxed wire is cleaner to handle; the coating does not flake or rub off. Borax gives a smoother surface after drawing. Borax-treated wires, after electrical resistance patenting, can be readily galvanized. Borax is not hygroscopic and protects treated wires for a certain time against atmospheric corrosion; it acts as a flux for welding and so facilitates the joining of coils for continuous operation. The methods of preparing, using, and controlling borax baths are described.—J. P.

Components of Wire Drawing Lubricants. L. Salz. (*Wire and Wire Products*, 1953, **28**, Oct., 1056–1058, 1125). The function, composition and physical properties of the principal types of wire-drawing lubricants are described.—J. G. W.

Control of Wire Drawing. O. Hermann. (*Draht, German ed.*, 1953, **4**, Oct., 373–377). The author points out that the drawing force is a sensitive index to changes in entry, diameter, wear of die, and lubrication. He therefore proposes that a continuous indication of die load be used as a means of continuous control. The design of an instrument for use with diamond dies is given together with an account of observations made with it. Failure of the die by cracking caused frequent jumps in the die load.—J. G. W.

Handling and Storing of Wire and Wire Products. C. C. Tappero. (*Wire and Wire Products*, 1953, **28**, Oct., 1050–1055). Particulars are given of handling and storing methods and facilities at the Pueblo Plant of the Colorado Fuel and Iron Corp.—J. G. W.

New Canadian High-Carbon Wire Mill. (*Wire Ind.*, 1953, **20**, Sept., 877–880). The newly established high-carbon wire mill of the Canadian Tube and Steel Products Ltd., Montreal, is described. A continuous strand patenting, cleaning, and coating line and a continuous annealing, cleaning, and galvanizing line have been installed by the Incandescent Heat Co., Ltd., Birmingham.—J. G. W.

A New Wire Industry in Ireland. (*Wire Ind.*, 1953, **20**, Nov., 1085–1092). A modern wire plant erected and opened in June, in Dublin, is described. The plant comprises cleaning house, wire-drawing mill, continuous galvanizing and annealing plant, and wire netting, stranding, and barbing sections. Total output of wire is intended to be 1600 tons/year.—J. G. W.

New Methods of Illumination in the Wire Industry. F. Baierl. (*Draht., Engl. Ed.*, 1953, Dec., 39–40). Basic requirements for good illumination are outlined with reference to the new German Standard Specification DIN 5035.—J. G. W.

ROLLING-MILL PRACTICE

Rolling Mill Motors. (*Technik*, 1953, **8**, Sept., 613–614). Details are given of motors constructed by the Niedersedlitz Works in Saxony for heavy plate and cogging mills with twin drives.—J. G. W.

Should One Use Solid or Segmented Resin Bearings in Rolling Mills? A. Keil. (*Technik*, 1953, **8**, Sept., 609–612). The author distinguishes between moulded plastic bearings and metal bearings lined with plastic. He pronounces in favour of the latter on the grounds of material economy, and describes in detail different designs and methods of manufacture.

The Determination of Rolling Times for Different Steel Qualities as a Basis for Reference-Ton Calculations in the Rolling-Mill by Means of the Records from an Autographic Recorder. F. Bleimann. (*Stahl u. Eisen*, 1953, **73**, Nov. 5, 1468–1472: *Iron Steel Inst. Translation Series No.* 480, 1954). Appropriate time studies, supplemented by the charts from a specially designed recorder, during a varied working schedule of a bar mill, have made it possible to derive valuable information relating to rolling times, work planning, standard cost, output prediction, bonus calculation, and pre-computing of rolling costs as related to steel quality, section, and batch size. Scientifically formulated works data had to be obtained over a long period to make statistical assessment possible. The automatic apparatus for recording rolling times and its method of operation are fully described.—J. P.

The Calculation of Roll Force and Torque in Hot Rolling Mills. R. B. Sims. (*Inst. Mech. Eng., Preprint*, Jan. 20, 1954). Equations are derived for the normal roll pressure, specific roll load, and torque in hot rolling mills, using the condition for plastic deformation in rolling derived by Orowan, together with von Kármán's equation of equilibrium. Although applying strictly to the rolling of ideal plastic-rigid materials, the author claims that the equations may be applied to the rolling of materials which strain harden, by using a mean value of the yield stress in the pass. The equations have been checked against measurements made when rolling pure lead at room temperature, and against the results of experiments on hot steel. There is close agreement between the calculated and measured roll loads, but the roll torque is overestimated slightly by the theory above reductions of about 30%. (14 references).—P. M. C.

Calculation of Roll Pressure and Energy Consumption in Hot-Rolling. G. Wallquist. (*J. Iron Steel Inst.*, 1954, **177**, May, 142–158). The paper shows that the calculation of roll pressure and energy consumption in hot-rolling may be based either on a mathematical analysis of the deformation or on empirical values obtained experimentally during rolling, the latter method being the only reliable one at present. Previous work in the field is reviewed. The present investigation includes studies on the deformation process in hot-rolling and the determination of numerical values for coefficients necessary for the calculations. The influence of steel composition, temperature, reduction, and material thickness on roll pressure, energy consumption, spread, and forward slip was studied on 16 steels. Tests were made in the new experimental mill at the Royal Institute of Technology, Stockholm. General methods for calculating roll pressure and energy consumption are described. Besides the specific roll pressure, the roll-pressure coefficient, previously used in cold-rolling calculations, is introduced. Part of the results are summarized in diagrams showing the specific roll pressure, the roll-pressure coefficient, and the torque-arm coefficient as functions of various rolling factors. The experimental results in their entirety will be reported later.

Measurement and Analysis of Rolling Loads in a Large Hot Plate Mill. R. Stewartson. (*Inst. Mech.Eng., Preprint*, Jan. 20, 1954). The design and construction of electrical resistance strain gauges for measuring roll loads up to 1000 tons are described. The load indications during the rolling of a variety of hot plates have been analysed and compared with three roll-load formulæ due to Ekelund, Orowan and Pascoe, and Sims. That due to Sims gives the best agreement, the calculated loads for reductions over 10% lying within ±25% of the measurements. The other two formulæ show discrepancies often exceeding 50%. Below 10% reduction all three formulæ give values for roll load much lower than those obtained by experiment.—P. M. C.

Erratum

In the last line of the abstract " The Continuous Rolling of Stainless Steel at the New Shepcote Lane Works, Sheffield ". (*J. Iron Steel Inst.*, 1954, **176**, Mar., 317) for " 33 ft. " read " 3 ft. 3 in."

Reconstruction of C. F. & I. Mill Increases Capacity and Flexibility. W. Brill and R. H. Wright. (*J. Met.*, 1953, **5**, Dec., 1623–1624). Expansion of the Pueblo plant of the Colorado Fuel and Iron Corp. has included reconstruction of the 25-in. structural mill to increase its capacity and flexibility. This reconstruction is described with particular emphasis on the installation and characteristics of the new 4000 h.p. mill motor.—G. F.

New Developments in the Manufacture of Reels for Wire-Rod and Light-Section Rolling Mills. H. Terhaag. (*Demag News*, 1953, (132), 9–12). The development of modern wire-rod rolling mills and more particularly continuous high-speed mills has brought with it special problems affecting the design of suitable coiling machines. These problems are discussed and work which has been carried out by DEMAG to solve them, with a short description of their latest design of rolling mill reels, are given.—B. G. B.

Miniature Steel-Strip Rolling Mill: Experimental Unit Made by Apprentices. (*Iron Coal Trades Rev.*, 1953, **167**, Dec. 11, 1368). A brief description is given of a small experimental strip-rolling mill made in the apprentice training centre of Richard Thomas and Baldwins Ltd. The mill is a 4-high 5 in. model, with back-up rolls 5¾ in. in dia. and work rolls 1¼ in. in dia.—G. F.

New Mill Helps Boost Rod Output. J. Delaney. (*Iron Age*, 1953, **172**, Aug. 27, 109–111). The new rod mill at Jones and Laughlin Steel Corp. Aliquippa plant uses diamond and square passes in the roughing stands and a unique design of housing. A hydraulic shifting mechanism is used to move the whole housing laterally to bring the groove to be used into alignment with the desired pass lines. For roll changing, the whole housing is replaced by a spare held in readiness. The mill rolls billets 2½-in. square and larger up to 30 ft. long at an average rate of 35 tons/hr., the top delivery speed being 5000 ft./min.—A. M. F.

Maximum Production on Hot Strip Mill. J. E. Angle. (Amer. Iron Steel Inst.: *Blast Furn. Steel Plant*, 1953, **41**, Nov., 1289–1294, 1311). An account of the activities and staff organizations of the 80-in. hot strip mill at the Gary sheet and tin mill is given. The author considers that the selection and maintenance of the management, organization, and the installation of adequate heating and coiling capacities are the essential requirements to obtain maximum production.

A Planetary Hot Rolling Mill. (*Engineer*, 1953, **196**, Oct. 23, 526–527). **Planetary Hot Rolling Mill for Steel Strip.** (*Engineering*, 1953, **176**, Oct. 30, 545–546). **Europe's First Planetary Mill on Show.** (*Sheet Metal Ind.*, 1953, **30**, Nov., 988). **New Planetary Hot Rolling Mill.** (*Brit. Steelmaker*, 1953, **19**, Nov., 628–632). **Planetary Hot Rolling Mill.** (*Iron Coal Trades Rev.*, 1593, **167**, Oct. 23, 961–962). A new hot rolling mill in which slabs are reduced to strip in a single pass has been installed at the works of Ductile Planetary Mills, Ltd. This mill design was developed by the Sendzimir organization and is known as a planetary mill. It produces strip from 6 to 15 in. wide and from 0·187 in. to 0·040 in. thick. Small work rolls are equally spaced round the periphery of large back-up rolls. The rate of slab feed is low whilst the planetary rolls are driven by their frictional contact with the back-up rolls at very high speed. The combined action of the many rolls as they pass over the slowly moving slab produces a continuous strip. Slabs of any length may be rolled as the length is not limited by stand spacing since one mill stand only is involved. The mill is designed to produce 10 tons of strip per hour.

On the Mechanics of Cutting Metal Strips with Knife-Edged Tools. R. Hill. (*J. Mech. Phys. Solids*, 1953, **7**, July, 265–270). A theoretical investigation is made of a cutting operation in which a strip is split in two across its thickness by a tool with a wedge-shaped cutter. Details of deformation, load, work done, and influence of friction and hardening are treated.—J. G. W.

Comparison of Methods of Calculating Torque and Specific Rolling Power During Cold Rolling without Front or Back Tension. K. Filasiewicz, Z. Wusatowski, and A. Galanty. (*Prace Instytutow Ministerstwa Hutnictwa*, 1953, **5**, (4), 199–208). [In Polish]. The formulæ usually applied and the method of calculating torque and specific rolling power during cold rolling without front or back tension are given. On the basis of data published in the technical literature concerning rolling in two-high, four-high and precision four-high stands, the torque and rolling power were determined using the above methods. Results by calculations and by measurements are compared.—V. G.

Contribution to the Problem of a Suitable Drive for Cold Rolling Reels. W. E. Baltz. (*Stahl u. Eisen*, 1953, **73**, Oct. 22, 1404–1409). Much progress has been made recently with drives for take-up and pay-off reels for cold reduction mills and all the equipment required for the construction and operation of high-speed plant can now be supplied. The problem of accelerating and retarding the reels while maintaining constant strip tension even during the briefest starting or braking periods has been satisfactorily solved. The procedures and equipment for doing this are described.—J. P.

The Computation of Loads in Metal Strip Rolling by Methods Involving the Use of Dimensional Analysis. M. Cook and R. J. Parker. (*J. Inst. Metals*, 1953, **82**, Nov., 129–140). The use of dimensional analysis has enabled accurate rolling-load data to be calculated for any rolling condition where the ratio of initial strip thickness to roll diameter lies between such wide limits as 1 : 40 and 1 : 800. The method requires relevant load data for a range of strip thicknesses and roll diameters but the measurements can be made on one mill only. The validity of this method is demonstrated by reference to published data for mild steel.—B. G. B.

Evaluating Rolling Pressures in Hot and Cold Strip Mills. N. H. Polakowski. (*Steel*, 1953, **133**, Nov. 2, 96–104). This is a review and brief analysis of data on direct measurement of roll separating forces under operating conditions. Data concerning a 66-in. hot strip mill consisting of four roughing stands and a 6-stand finishing train, two 5-stand tinplate mills, and a 3-stand tandem mill are presented. The results are compared and commented on.—D. L. C. P.

Improvements in Steel Handling Layout. (*Mech. Handling*, 1953, **40**, Oct., 468–470). Details are given of the layout of new rolling mills of the Consett Iron Co. Ltd. The layout consists of three rolling mills on a single roller table line served by intermediate side off-takes with suitable cooling and parting-off equipment.—D. H.

MACHINERY FOR IRON AND STEEL PLANT

Gas Turbine. R. Barbier. (*Acero y Energ.*, 1953, **10,** Sept.-Oct., 35–41). [In Spanish]. The author discusses the present development and future outlook of the gas turbine and reviews its field of application. The first gas turbine in Spain and the first in the world to be used for supplying air blast to the Bessemer converters has been installed at the plant of the Altos Hornos de Vizcaya. It is described and illustrated.—R. S.

A High-Temperature Power Station with a Live Steam Temperature of 610° C. (*Z.V.d.I.*, 1953, **95,** Aug. 21, 802–829). In November, 1951, a high-temperature power station operating at 160 atm. with a live steam temp. of 610° C. was put in commission at Farbenfabrik Bayer A.G., Leverkusen. At a meeting of the V.D.I. in 1953 several papers on this plant reporting experience after 10,000 hr. running were presented. Abstracts of the papers follow :

Planning. H. Tietz. (802–809). Reasons are given for the choice of operating pressure and temperature, steam circuit, and materials for different components. The relative merits of ferritic and austenitic steels are discussed with reference to operational experience.

Evaluation of the Boiler Material and Determination of the Plate Thickness. H. Buchholtz. (809–811). The creep strength of alternative materials for the boiler was studied before the choice was made. The tests are discussed.

Materials for Boiler and Pipe Lines. M. Werner and W. Ruttmann. (811–817). Nine steels were examined with reference to impact strength, creep strength, stability of austenite, stress corrosion, welding procedure, and weldability. The result of these studies was that ferritic steels were used exclusively for service below 525° C., and niobium-stabilized 16/13 Cr–Ni steel for higher temperatures.

Turbine Materials. R. Schinn. (818–822). Six steels (one 16/13/1·32 Cr–Ni–Ti steel ; three Cr–Ni–Mo steels ; and two Cr–Mo steels) were examined with reference to creep strength and surface hardness. Various attempts were made to enhance the surface of austenitic steels and are discussed. A comparison is made between heavy austenitic steel castings and forgings for the turbine housing.

Manufacture of Pipes and Headers and Experiences Gained Thereby. H. Buchholtz. (822–824). Notes made during the manufacture of the austenitic steel pipes and headers are summarized. To prevent carburization of tubes they were initially decarburized by passing wet hydrogen through them.

Special Problems. H. Tietz. (825–826). The following topics are discussed : Effect and properties of feed waters, particularly their mineral content, and temperature distribution in the superheater tubes.

Durability of Materials. M. Werner and W. Ruttmann. (827–828). Performance in service is reported, and some cases of failure are described.

Operating Experience to Date. H. Tietz. (828–831). Operational experience with the plant is summarized and preliminary conclusions are stated concerning the suitability of the steels. Further development in turbine construction and plant design are forecast.—J. G. W.

Power for a Walking Dragline. (*Elect. Times*, 1954, **125,** Jan. 14, 43–48). The construction of an induction-type frequency booster to supply power to a dragline excavator of American manufacture is described. This booster was necessary to obtain 60 cycles for dragline motors from the 50 cycle supply in England.—V. G.

Belt Conveyors. M. Garnier. (*Rev. Ind. Min.*, 1953, **34,** Sept., 654–659). The essential components of belt conveyors are outlined and general considerations for their installation and use are given. Factors mentioned include band width in relation to material size, capacity, speed, power, gradient and change of gradient, band tension, charge, and band life.

Selection of Conveyors for Handling Hot Bulk Materials. J. W. Snavely. (*Min. Eng.*, 1953, **5,** May, 512–517). A discussion is presented of the factors determining the use of conveyors for handling bulk materials when the temperature exceeds 400° F. Types considered are cast steel drag chain, cast pans, and outboard roller steel pan conveyors, and bucket elevators utilizing various constructional materials.—K. E. J.

An Investigation of Cemented Tungsten Carbide as Bearing Material. J. S. Kozacka, H. A. Erickson, H. W. Highriter, and A. F. Gabriel. (*Trans. Amer. Soc. Mech. Eng.*, 1953, **75,** Oct., 1203–1209). The paper is a progress report of an investigation to measure the performance of cemented tungsten carbide bearings using different lubricating oils under varying load conditions. It is concluded that such a bearing with a journal of the same material can be run successfully under proper lubricating conditions at a sustained high bearing pressure.—D. H.

Functions of Materials in Bearing Operation. P. P. Love, P. G. Forrester, and A. E. Burke. (*Inst. Mech. Eng., Auto. Div., Preprint*, Feb. 12, 1954). The numerous factors affecting the operation of plain bearings, (forces, relative motion, ambient conditions, and properties and design of bearing, journal, and housing) are considered, and the problem of bearing design is discussed. A study is made of the three kinds of bearing failure, namely, seizure, excessive wear, and mechanical breakdown. (18 references).—P. M. C.

Bearings, Lubricants, and Lubrication. (*Mech. Eng.*, 1953, **75,** Oct., 801–808). The paper is a digest of the 1952 literature on bearings and bearing materials and automotive, gear and metal working lubricants, and lubrication. (124 references).—D. H.

LUBRICANTS AND LUBRICATION

The Physics of Lubrication. M. Kühn. (*Stahl u. Eisen*, 1953, **73,** Oct. 22, 1418–1422). The literature is reviewed. (38 references).—R. A. R.

Molybdenum Disulphide as a Lubricant. (*Machinery*, 1953, **83,** Aug. 21, 367–369). The physical structure, physical and chemical properties, and lubricating properties (with consideration of temperature effects) of molybdenum disulphide powder are given and the lubricating properties of oils and greases containing molybdenum disulphide are then considered.

Colloidal Graphite Keeps Bearings Rolling at 600° F. During Box Spring Finishing Operation. (*Indust. Heating*, 1953, **20,** Oct., 2036–2038). A walking beam arrangement is used to trip poppet valves and position twin nozzles to spray a 9% ' Oildag ' suspension into bearings exposed to oven temperatures of 600° F.—R. W. B.

WELDING AND FLAME-CUTTING

The Development of Metal-Arc Welding and Electrodes During the Past Half-Century. E. Flintham. (*Brit. Welding J.*, 1954, **1,** Jan., 3–10). The paper describes the early types of electrodes and arc-welding processes, and reviews the progress of metal-arc welding.—U. E.

Core Wires for Welding Electrodes. K. L. Zeyen. (*Draht, Engl. Ed.*, 1953, Dec., 19–24). Chemical compositions of core wires specified in German, Russian, American, and British standards are compared and reference is made to investigations at the Battelle Memorial Institute into the influence of the composition of core wire on the welding properties of coated electrodes, weld strength, and porosity.—J. G. W.

Some Aspects of the Studies on Weldability Carried Out in France at the Institut de Soudure. H. Granjon. (*Rev. Soudure*, 1953, **9,** (3), 140–151). The author reviews the work done in the last few days at l'Institut de Soudure and describes research conducted. The variation in the properties of the base metal close to the weld, as well as ' overall ' weldability which determines the general suitability of steels for welding are discussed. Data on the weldability of steels, welding techniques and tests, and the effects of heat-treatment are given. (16 references).—M. D. J. B.

Weldability of Structural Steels. L. Knez. (*Varilna Tehnika*, 1953, **2,** (3), 61–64). [In Serbo-Croat]. A survey is made of factors, such as composition, shape of welded material, stresses, thermal expansion, and skill of the welder, which influence the quality of welds in low-alloy steels. Tests of weld quality are discussed and the more common types of failures considered.—P. F.

How to Butt-Weld 0·005 in. Stainless Steel. M. S. Weinstein. (*Machinist*, 1953, **97,** Oct. 3, 1653–1655). A method of fabricating minature ' **T** ' and ' **I** ' sections from stainless steel strips 0·008 in. thick by butt-welding has been developed by the author at the U.S. Navy Ordnance Laboratory. The method of welding employed is of condenser discharge technique and a semi-automatic action using the overarm of a milling machine and a reciprocating electrode is described.

Effect of Steel Quality on Spot-Welding Properties. J. E. Roberts and H. E. Dixon. (*Brit. Welding J.*, 1954, **1**, Jan., 27–35). Experiments to determine differences in spot weldability between five grades of 18 S.W.G. low-carbon steel, and of deep-drawing quality, are described. Welds were tested after various periods to assess ageing. Values of shear strength were generally greater than 0·7 ton and no ageing was observed. A low value of tensile strength appeared in the fully killed open-hearth steel and deep-drawing steel after medium-current welding.—U. E.

Study on Experimental Manufacture of High Tensile Steel Sheets for Electric Welding. K. Horikawa. (*Tetsu to Hagane*, 1953, **39**, July, 705–715). [In Japanese]. Results are reported from wartime studies made by Japanese Navy technical staffs Several steels were examined as alternatives to manganese-bearing low-alloy steel, with a view to superior weldability. The best results were obtained with steel of composition C 0·15–0·20%, Si 0·3–0·7% and Mn 0·9–1·2%. Tensile strength was 52–60 kg./sq. in. and other properties are quoted.—K. E. J.

Automatic Welding in Castings Repair. (*Canad. Metals*, 1953, **16**, Oct., 54–58). Details of a test carried out to check the speed and economy of repairing defects in steel castings by semi-automatic arc welding as against the normal manual methods, are given. The results showed that casting repairs could be made at a saving of 50% or better by the semi-automatic equipment together with improvement in strength and quality of the welds.—B. G. B.

Photographic Inspection Spots Defective Brazing. M. A. Slairetam. (*Mat. Methods*, 1953, **38**, Aug., 94, 95). Photographs of red-hot steel aeroplane propeller blades are being used by Aeroproducts Operations, Allison Div., of General Motors Corp., Ohio, to detect imperfections in brazing. The exposures are made whilst the blades (10 ft. 6 in. long) are cooling after heat-treatment, voids in the brazed regions showing up as cool spots. Exposures are made on Kodak Plus-X film at f3·5 for $\frac{1}{25}$ sec.—P. M. C.

MACHINING AND MACHINABILITY

Abrasive Wheel Doubles Tube Cutting. (*Steel*, 1953, **133**, Dec. 28, 79). An abrasive-wheel cutting machine is described, with which the Ryan Aeronautical Co., San Diego, accurately cuts short pieces from 20 ft. lengths of stainless steel tube and rod. The burr can be removed by tumbling. The method is a considerable improvement over lathe cutting in speed and economy.—D. L. C. P.

How Do Boron Steels Compare in Machinability? N. Zlatin, J. F. Kahles, and W. F. Friedlander. (*Iron Age*, 1953, **172**, Oct. 29, 94–97). Tests have been carried out by the Watertown Arsenal on six standard alloy steels and seven equivalent boron steels ; both surface finish and tool life have been compared. Results show that the boron steels possess better machining characteristics. This difference is usually more pronounced in cutting with high-speed steels than in machining with carbides.—A. M. F.

Machinability of High-Phosphorus Irons Improved by Ladle Additions. E. A. Loria. (*Machinist*, 1953, **97**, Oct. 3, 1658–1661). The author describes the testing of high-phosphorus irons having various ladle additions to improve machinability and deals mainly with four different testing procedures : tool-wear, constant-pressure turning methods, drilling, and turning. A table shows how these irons responded to these machining tests.—M. A. K.

The Effects of Cold-Drawing, Microstructure, and Thermal Treatments on the Machinability and Mechanical Properties of Carbon and Alloy Steel. F. E. Dreves. (*Trans. Amer. Soc. Mech. Eng.*, 1953, **75**, Oct. 1219–1232). Various cold finishing operations such as drawing, straightening, turning, centreless grinding, and polishing are described briefly. The effects of cold drawing on the machinability and mechanical properties of certain plain carbon free-machining steels and medium carbon Ni–Cr and Ni–Cr–Mo constructional steels are explained. The influence of microstructure on the machinability of these steels is discussed together with the common thermal treatments used to control it.—D. H.

Machining of High-Tensile-Strength Steel. F. M. Rayburn. (*Mech. Eng.*, 1953, **75**, Oct., 794–795). The author describes the routine procedures used by the Monasco Manufacturing Co., (U.S.A.) for machining 4340 steel (0·38–0·43% C, 1·6–2·0% Ni, 0·7–0·8% Cr, 0·2–0·3% Mo) heat-treated to tensile strength of 80–90 and 90–100 tons/sq. in.—D. H.

Making Precision Roller Chain. (*Machinery*, 1953, **83**, July 31, 195–203). The article describes the production of precision roller chain at the Perry Chain Co., Ltd., Birmingham, giving details of the plant layout, machines, and tools.—J. R. P.

Reducing Machining Times by the Use of Carbon Dioxide Coolant. E. W. Bartle. (*Machinery*, 1953, **83**, July 24, 172–174). In the production of heat-resisting parts of highly alloyed steels, which are difficult to machine, the cutting speeds and feeds have been increased by as much as 100% by employing liquid CO_2 to absorb the heat that is generated. Examples of the employment of this coolant are described.

Ultrasonics Cuts Carbide with Mild Steel Tools. R. G. Wood. (*Machinist*, **97**, Sept 26, 1601–1603). The use of a new ultrasonic machine tool for machining tungsten and titanium carbides, hardened tool steels, molybdenum, and other tough metals as well as diamond, aluminium oxide, quartz, and glass is briefly described. The machines, of American design now available in England, will speed up the production of tungsten-carbide wire drawing dies.—M. A. K.

Electrospark Machining. C. R. Alden. (*Mech. Eng.*, 1953, **75**, Sept., 701–705). The author reviews the progress made in the direct application of electricity to machining materials, with emphasis on the potentialities of these processes for future development. Particular reference is made to electrospark machining as carried out in the ' Method X ' type of machine.—D. H.

Electrolytic Machining. A. G. Thompson. (*Machinist*, 1953, **97**, Oct. 3, 1650–1652). An electrolytic machining technique has been developed by the Metallurgical Division of the National Physical Laboratory to produce small specimens for micro-tensile tests. The author describes electrolytic machining of hard surfaces not possible by normal turning, and deals with the problem of selecting the most suitable electrolyte for various materials.—M. A. K.

The Band Grinding Process. O. Schleppi. (*Metalloberfläche*, 1952, **6**, Feb., A23–A26). Various types of band grinders are described, and their applications are outlined.

Lapping. H. Finkelnburg. (*Metalloberfläche*, 1952, **6**, Jan., A9–A14). Lapping is compared and contrasted with processes such as grinding and honing. More material can be removed by lapping than by boring and similar treatments, but a much finer finish is obtained than is possible by grinding. Equipment for lapping a variety of products is described and illustrated.—L. D. H.

Lubrication In the Cutting of Metals. A. Niedzwiedzki. (*Machinery*, 1953, **83**, Oct. 9, 717–721). The author describes the factors influencing the problems of fluid lubrication in cutting operations. The function of lubrication and the properties of lubricants, *i.e.*, viscosity, oiliness, film strength, penetration, and resistance to decomposition are discussed.

Measuring Surface Roughness. (*Canad. Metals*, 1953, **16**, Oct., 66–67). Optical and stylus methods of measuring surface roughness are briefly discussed. Details of a new electronic roughness tester, particularly suitable for the workshop, which can be used for measuring surface roughness against chosen standards, are given.—B. G. B.

A Method of Measuring Surface-Quality in the Workshop. H. van Dam. (*Machinery*, 1953, **83**, July 31, 211–212). A description is given of the preparation of synthetic plastic resin replicas of surface contour to facilitate the measurement of surface quality of a work piece without its removal from the machine.—J. R. P.

Surface Finish and Its Measurement by Electronic Methods. S. F. Smith. (*J. Trans. Soc. Eng.*, 1953, **44**, Oct.–Dec., 133–154). Surface finish requirements and its measurements are discussed. Some modern laboratory and workshop equipment is described.—V. G.

CLEANING AND PICKLING

Abrasive Shot Cuts Sheet, Strip Cleaning Costs. G. D. Dill. (*Iron Age*, 1953, **172**, Oct. 29, 91–93). Blasting of hot-rolled steel strip and sheet with abrasive steel shot as a cleaning process is shown to be cheaper than pickling. The abrasive is thrown mechanically from high-speed wheels. Gauges as thin as 18 may be cleaned in this way, and speed of operation can be as high as 150 ft./min.—A. M. F.

Blasting with Metallic Abrasive. A. Ambrogi. (*Fonderia Ital.*, 1953, **2**, Oct., 631). [In Italian]. The author briefly describes the advantages derived from adding metallic abrasives to sand for surface cleaning and considers the pros and cons of spherical and angular particles.—M. D. J. B.

How to Use Steel Balls and Shapes for Barrel Finishing. R. M. Terry. (*Precision Met. Mold.*, 1953, **11,** Aug., 47–52). Details are given of the barrel finishing process using steel balls, cones, diagonals, ovals, and pins. Practical information is given on the size and shape of the mills and the selection and care of balls and shapes.—D. H.

Pitting Corrosion of Stainless Steels. N. Solony. (*Canad. Metals*, 1953, **16,** Sept., 50–51). The acid pickling of stainless steels with a view to the reduction of pitting corrosion, is discussed. The determination of the correct ratio of nitric to hydrochloric acid is considered.—B. G. B.

Studies of Electrolytic Polishing. S. Tajima. (*Metalloberfläche*, 1952, **6,** Apr., B54–B58; May, B73–B75). The author reviews the development of electrolytic polishing in Japan, mainly during the 1939–45 war. Subjects covered are: Fundamental principles, application of various baths and installations, and the mechanism of the process. The present position and lines of development of electrolytic polishing in Japan are described.—L. D. H.

Electropolishing. A. T. Steer, J. K. Wilson, and O. Wright. (*Aircraft Prod.*, 1953, **15,** July, 242–249). The influence of electropolishing on the fatigue endurance limit of ferrous and non-ferrous parts has been investigated and the results are discussed. Some method of treatment after electropolishing is essential in order to increase the fatigue-endurance limit which has been considerably lowered by the electropolishing treatment. Vapour-honing and heat-treatment are considered for this purpose.—B. G. B.

What Must the User of a Grinding Wheel Know? B. Kleinschmidt. (*Giesserei*, 1953, **40,** Oct. 29, 585–589). Particulars of grinding wheels now available follow a brief account of the development of the abrasive industry. The grinding wheel manufacturer's point of view is given and discussions are presented on the various aspects of grinding, *e.g.*, the type of machines, the procedure, the type of coolant.—R. J. W.

Grinding and Polishing Media. W. Burkart. (*Metalloberfläche*, 1952, **6,** Jan., A1–A4). A large number of grinding and polishing media are classified according to the surface properties required, and their properties are briefly outlined.

Grinding and Polishing Processes. W. Burkart. (*Metalloberfläche*, 1952, **6,** May, B70–B72). The author defines, compares, and summarizes briefly the principle characteristics of grinding, lapping, boring, and hand and mechanical polishing.

Industrial Fine Grinding of Round Parts. before Electroplating. W. Hofmann. (*Metalloberfläche*, 1952, **6,** Jan., B1–B5). The principle and mode of operation of several fine-grinding machines for the preparation of articles to be plated is described, and illustrated by examples.—L. D. H.

Galvanic Descaling, Derusting, Deburring, and Polishing, and a Method of Acid Galvanizing. R. Beck. (*Draht, Engl. Ed.*, 1953, Mar., 42–43). The 'Dynamisater' A.C. process for derusting and descaling of wire is described and a prototype installation, tested in 1952, is illustrated. It is claimed that the cost per ton of wire treated was reduced by nearly 60%.

A Suitable Arrangement for Bath Heaters in Pickling Tanks. W. Mazurzak. (*Draht, Engl. Ed.*, 1953, Mar., 38–39). A design of brick pickling tank for wire, with recesses for acid-proof porcelain-sheathed electric immersion heaters, is illustrated and described.—J. G. W.

PROTECTIVE COATINGS

Selecting Protective Coatings for Metals. J. C. Campbell. (*Mat. Methods*, 1953, **38,** Aug., 109–124). The author gives a functional guide to the proper choice of protective coatings for iron, steel, and the commoner non-ferrous metals. Protection from the effects of atmosphere, soil, water, and chemicals is considered, emphasis being placed on the corrosive conditions, mechanical durability, appearance, and cost. Conversion, organic, metallic, and vitreous coatings are discussed.

Union Switch and Signal Operates New Electroplating Plant. H. E. Trout, jun. (*Steel Processing*, 1953, **39,** Oct., 516–520, 530, 531). This plant, opened in May, 1953, and occupying an 18,000 sq. ft. single storey building, is described and illustrated. A flow sheet and plant layout plan is shown. Fully automatic, semi-automatic, still, and barrel plating facilities are available for copper, cadmium, nickel, tin, zinc, and chromium.—P. M. C.

Plated Coatings—Designers Weigh Tin Alloys. F. A. Lowenheim. (*Steel*, 1953, **133,** Nov. 30, 110–112). The prospects of using tin in conjunction with other metals for electroplating are discussed. Tin–lead and tin–zinc are suitable for anti-corrosion coatings; tin–nickel and tin–copper are suggested for decorative finishes. Three examples of plating-baths are given.—D. L. C. P.

Metallic Coatings on Steel. D. L. Phillips. (*Swansea Met. Soc., Advance Copy*, Jan. 10, 1953; *Iron Steel Inst. Special Report No.* 49, 1954, 1–8). The main factors affecting protective properties of coatings for steel, such as the chemical and physical properties of the steel base and coating metal before application, and methods of application, are discussed. The work at B.I.S.R.A. Sketty Hall Laboratories in this field is outlined.—V. G.

Defects in Electroplating in Drums and Bells. O. Niedermeyer. (*Metalloberfläche*, 1952, **6,** Jan., B10–B11; Feb., B24–B25). The author discusses difficulties encountered in the large scale electroplating of small parts, and suggests measures for obviating these difficulties. He recommends degreasing in heated iron drums, and pickling in rotating drums. The importance of correct bath composition, and current density and distribution are emphasized. Some applications of these principles are given.—L. D. H.

Better Protection. Lower Packaging Costs with V.P.I. Wrapping. E. J. Smith. (*Iron Age*, 1953, **172,** Oct. 15, 111–113). The application of vapour protective wrapping paper for storage and shipment is described. Reduced handling costs and no protective greases to be removed are some of the advantages.—A. M. F.

Some Typical Applications of the Fescol Electro-Deposition Process. (*Machinery*, 1953, **83,** July 24, 161–167). It is claimed that the specialized methods of pre-treatment of components, in Fescol electrodeposition ensure a maximum bond strength. Applications of deposits of nickel and chromium are referred to. The application of chromium deposits to valves, gauges, plugs, and broaches is described.—J. R. P.

Contact Immersion-Plating. J. K. Wilson and O. Wright. (*Aircraft Prod.*, 1953, **15,** Sept., 329–334). The problems involved and the methods used for the deposition of protective metallic coatings on internal surfaces and parts of difficult shape are considered. Contact immersion plating and electroplating methods are considered.—B. G. B.

The Measurement of Thickness Based on the Reflection of β-Rays. I. Dujardin. (*Peintures, Pigments, Vernis*, 1953, **29,** Nov., 906–911). The principle of this method of measuring thickness is explained. The method is suitable for measuring the thickness of chromium and nickel coatings, among others. The limits of its application are considered together with the optimum conditions for carrying out the measurements. The method is compared with ultrasonic and magnetic methods.—B. G. B.

Mathematical Determination of the Thickness of Coatings on Wires of Round Cross Section. A. Zastera. (*Draht, Engl. Ed.*, 1953, Mar., 48–49). Formulæ and diagrams for the determination of coating weight and thickness are derived.

Principles of the Magneto-Inductive Measurement of Non-Ferromagnetic Layers on Iron Bases, Particularly with Varying Radii of Curvature. P. Koch. (*Metalloberfläche*, 1952, **6,** May, A67–A70). An investigation was carried out into the possibility of measuring by magneto-inductive methods non-ferromagnetic layers on an iron base. It was derived from physical considerations that faults in measurement could arise through scattering of the magnetic field at the curved iron surface. A graphical method was devised for evaluating layers on iron bases with radii of curvature of 5 to 500 mm. Other sources of error are indicated.—L. D. H.

Hard Chrome Solutions, Which Offers Better Plating Properties? R. A. Balbierz and H. D. Burgess. (*Iron Age*, 1953, **172,** Oct. 22, 126–130). Chromic and sulphuric acid baths for chromium plating are compared with a recently developed fluoride-catalized bath. With the latter, deposits are better distributed, harder, and have less effect on the fatigue life of the base metal. In addition, the baths have better throwing power, faster deposition rate, and higher cathode efficiency. Analytical control of the bath is simple requiring only specific gravity checks and occasional analysis.—A. M. F.

The Diffubrite Chromium Diffusion Process. (*Machinery*, 1953, **83,** Nov. 6, 891–895). A process of chromium diffusion, or chromizing, as a means of providing protection against wear, heat, and the more common corrosive substances, is operated by Diffusion Alloys Ltd. under the trade name of 'Diffubrite'. The article describes the process and its economic aspects and discusses the problems of welding,

soldering, and general working of the components after treatment.—M. A. K.

Preparation for Hot Galvanizing. W. Haarmann. (*Draht, Engl. Ed.*, 1953, Mar., 50–51). Various precautions to be observed when galvanizing hollow-ware are listed.—J. G. W.

Galvanizing Furnace with Combined Heating by Radiation and Circulation. H. Rückemesser. (*Draht, Engl. Ed.*, 1953, Dec., 41–42). A novel design of galvanizing furnace is illustrated and described. The use of high-efficiency gas burner has raised the throughput.—J. G. W.

Difficult Galvanizing Jobs Done in New Radiant Furnace. R. C. Boehnke. (*Indust. Heating*, 1953, **20,** Sept., 1702–1706, 1842). A galvanizing furnace heated with a new design of gas-fired radiant burner is described. The temperature of the bath is kept at 850° F. with a variation of only 5°, and this accurate control has resulted in very uniform coatings.

Australian Developments in Drawn Galvanized Rope Wires. F. W. Welshman and C. James. (*Wire Prod.*, 1953, **3,** Dec., 6–8). Details are given of the process of galvanizing and subsequent drawing of high-tensile wire at Rylands Bros. (Aust.) Pty, in Australia.—J. G. W.

The Formation of White Spots on High-Gloss Tinned Sheet. J. Teindl. (*Hutnické Listy*, 1953, **8,** (4), 179–185). [In Czech]. The occurrence of grey patches and white spots was observed on large tinned sheets (90–120 g. tin per sq. m.), all of which had been hot-rolled. The primary cause of the formation of white spots was the presence of oily films and reaction products formed during bright-annealing. Clean surfaces and constant control of the tinning process are necessary to reduce the rejects thus caused.—P. F.

Hot Dip Aluminising. M. L. Hughes and D. P. Moses. (*Metallurgia*, 1953, **48,** Sept., 105–122). The published information on the hot-dip aluminizing process is reviewed and details of work carried out at Swansea by B.I.S.R.A. are presented. The effect on the product of variations in the aluminizing process is examined. Experimental batch aluminizing procedures and the operation of a pilot plant for continuous coating are described. The advantages and disadvantages of the process are discussed.—B. G. B.

Silicone–Aluminium Paints Stretch High-Temperature Life of Steel. A. E. Durkin and A. H. Horner. (*Mat. Methods*, 1953, **38,** Sept., 114–116). Brief details are given of the protective qualities of aluminium-pigmented silicone coatings at high temperatures. Coated mild steel is suitable for indefinite exposure up to 1000° F., and short time exposure up to 1600° F. On stainless steel, improvement in resistance to oxidation is evident after over 200 hr. at 1600° F.—P. M. C.

Heat Resistance of Steels Coated with Aluminium and Aluminium-Rich Alloys. Z. Kadefávek. (*Hutnické Listy*, 1953, **8,** (4), 185–191). [In Czech]. Aluminium coatings were applied to steels by three methods and the heat resistance of the layers was studied. Aluminium sprayed on to steel easily diffuses into it at temperatures in the 900–1000° C. range, the rate of diffusion not varying greatly with the composition of the steel. Sprayed-on layers result in thin coatings which practically disappear into the steel by diffusion on prolonged heating (24 hr.) at 1100° C. The heat resistance of chromium steels is not appreciably increased by spraying with aluminium.—P. F.

Flux Supplies Alloy for Hard Surfacing Manipulators. F. H. Knibbs. (*Iron Age*, 1953, **172,** Oct. 29, 98–99). Hard surfacing by a new technique in which the alloy content of the deposited metal is supplied by the flux rather than the electrode wire is described. Deposits on blooming mill manipulators have a Rockwell hardness of 45–50° C. The flux contains sufficient carbon, chromium, and molybdenum to produce semi-austenitic deposit.—A. M. F.

Flame Spraying of Non-Metallic Coatings on Metal Surfaces. H. Reininger. (*Metalloberfläche*, 1952, **6,** May, A71–A76). A survey is made of methods used in Germany and elsewhere for the flame spraying of plastic coatings on to metallic surfaces. The apparatus used is described, the conditions necessary for successful working indicated, and the properties of the coatings are outlined.—L. D. H.

New Vinyl-Metal Sheet. P. O'Keefe. (*Mat. Methods*, 1953, **38,** Sept., 94, 95). A process has been developed by the Naugatuck Div. of the U.S. Rubber Co., to bond rigid and semi-rigid vinyl films to steel and aluminium sheets. The resulting laminate has the strength of the base metal plus the corrosion resistant and attractive appearance of the vinyl coating. The laminate is made by a rolling operation, (details not disclosed), and can be subsequently formed and deep drawn. Excellent abrasion and corrosion resistance are claimed, and the cost is below that of stainless steel but above that of galvanized steel.—P. M. C.

Tone and Brightness Variations of Titanium-Oxide Self-Opacified Enamels. N. S. C. Millar. (*Inst. Vitreous Enamellers Ltd., Bulletin*, 1953, **4,** Nov.).

Vitreous Enamelling in Sweden, Denmark and Finland. J. H. Gray. (*Found. Trade J.*, 1953, **95,** Dec. 3, 679–686; Dec. 10, 725–727; *Inst. Vitreous Enamellers Ltd., Bulletin*, 1953, **4,** Nov.). This is a review of the vitreous enamelling industries in Sweden, Denmark, and Finland, outlining the type of work being carried out and the materials and finishes employed.—B. C. W.

Investigation of Gases Evolved during Firing of Porcelain Enamels. D. G. Moore and Mary A. Mason. (*J. Amer. Ceram. Soc.*, 1953, **36,** Aug. 1, 241–249). A detailed account is given of the methods employed in an investigation of the nature of gases evolved when vitreous coatings are applied to low-carbon steel. The source of the gases and the mode of formation of the gas bubbles are considered.—J. R. P.

A Study of Fishscaling Produced by Induction of Hydrogen into Enamelled Iron. E. E. Bryant, B. J. Sweo, G. E. Miller, and M. L. Simmons. (*Bull. Amer. Ceram. Soc.*, 1953, **32,** July, 248–252). A description is given of tests carried out on the delayed fish-scaling which may occur months after enamelling, even when the adhesion appears adequate. The diffusion of hydrogen through iron by acid attack and electrolytic means were employed to produce the fish-scaling. Ground coat and cover coat enamels were examined. The acceptance of hydrogen, diffusion of hydrogen through iron, and the evolution of hydrogen from iron were studied.

Finishing of New Republic Steel Kitchens. (*Indust. Heating*, 1953, **20,** Nov., 2255–2270). Details of the six-stage bonderizing and painting process are given. Spraying of all solutions, maintained at constant temperatures, is practised. Standby burners are provided in case of failure of steam heated coils.

POWDER METALLURGY

Recent Developments and Trends in Powder Metallurgy. H. W. Greenwood. (*Metal Treat. and Drop Forg.*, 1953, **20,** Sept., 427–429, 431). A brief review is presented of the applications of infiltrants, both to improve mechanical properties and to produce self-lubricating parts. The production of stainless steel powders, and sintered aluminium powder are also outlined, and the merits of carbide dies for the pressing operations are emphasized.—P. M. C.

The Preparation of Alloys by Powder Metallurgy. V. Vamberský. (*Hutnické Listy*, 1953, **8,** (5), 235–241). [In Czech]. Factors influencing the quality of ferrous and non-ferrous alloy prepared by powder metallurgy, particularly sintering temperature, particle size, specimen dimensions, structure, and hot-working are surveyed. A new method of making sintered alloys, to be fully described in a forthcoming paper, had been applied with success to 'Kovar' alloys containing about 29% Ni, 17% C oand 54% Fe. It facilitates the cheapening of production and improvements in quality. The usefulness of magnetic methods of studying sintering is emphasized, and a simple instrument is described.—P. F.

Sinter Materials: Fusion Metallurgy—Powder Metallurgy. F. Benesovsky. (*Industrielle Organisation*, 1953, **22,** 8, 311–316, Reprint). The author discusses the use of sintering and casting techniques in the manufacture of metal articles, and indicates factors which influence the choice of process.

Contribution to the Theory and Practice of Grinding Metal Powders in Ball Mills. M. Petrdlík. (*Hutnické Listy*, 1953, **8,** (5), 241–246; (6), 297–301). [In Czech]. The development of ball mills for the production of metal powders, and the theory and practice of grinding powders are discussed.

Properties of Metal Powders Reduced by Means of Hydrogen at Low Temperatures. M. Petrdlík. (*Hutnické Listy*, 1953, **8,** (5), 252–254). [In Czech]. Cobalt, iron, and copper powders formed by reduction in hydrogen at comparatively low temperatures were found to have good sintering properties. Higher oxygen contents, resulting from low-temperature reduction, did not affect sintering adversely under certain conditions.—P. F.

The Oxidation Process in Titanium-Carbide/Cobalt Hard Metals. W. Kinna and O. Rüdiger. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 535–542). The scaling mechanism of a carbide alloy (82% TiC + 18% Co) was investigated.

A parabolic rate law holds in the range 600° to 1000° C. Two oxide layers have been found : an outer one of CoO or Co_3O_4 and an inner one of TiO_2 with interspersed metallic cobalt. Above 1000° C., cobalt titanate $CoTiO_3$ was also detected. The structure of the scale is associated with the relative increase in volume on oxidation of the cobalt and the titanium carbide.—J. P.

Republic Steel Corp. to Produce Powdered Iron by New Process. (*Indust. Heating*, 1953, **20,** Nov., 2228–2230). Brief details are given of the reduction of beneficiated ores by hydrogen produced as a by-product from an adjacent petrol refining plant. Output will be 50,000 lb./day.

High Frequency Cores.—An Important Use for Powdered Iron. R. D. Ponemon. (*Precision Met. Mold.*, 1953, **11,** Aug., 30–32). The advantages of iron powder cores for high frequency use are discussed. A brief description is given of the methods of manufacture.—D. H.

PROPERTIES AND TESTS

The Philosophy of Simulated Service Testing. S. A. Gordon. (*Bull. Amer. Soc. Test. Mat.*, 1953, Oct., 27–31). A short philosophical discussion on the simulated service testing of machinery and machine parts is presented.—B. G. B.

Measurement of Young's Modulus with Coupled Pendulums. L. Jeníček. (*Hutnické Listy*, 1953, **8,** (7), 338–342). [In Czech]. The time taken for the transfer of energy from a swinging pendulum suspended at one end of a beam to a stationary pendulum suspended at the other, is proportional to the modulus of elasticity of the beam. The author describes tests in which this principle was used to determine changes in the elastic modulus with temperature in the 0–600° C. range of several steels, grey cast iron, and sintered carbides. Small specimens and small loads can be used, so that the method is useful for brittle materials.—R. A. R.

Plastic Deformation and Failure During Torsion. F. P. Rybalko. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93,** (3), 471–473). [In Russian]. The problem of the relation between the beginning of physical softening and the appearance of macrocracks or failure was investigated using steel 45-Kh-NMFA. Torsion tests under load to complete failure were made using a series of test pieces of varying plasticity obtained by tempering at different temperatures (between 100 and 650° F.) specimens previously quenched in oil from 900° C. The deformation zone of all test pieces was well polished. The use of chemical colouring enabled cracks 1–1·5 mm. wide and 5–10 mm. long to be observed. From experimental evidence it is concluded that : (1) In plastic materials the process of physical softening commences in the early stages of plastic deformation ; (2) the amount of relative slip before the appearance of zones of local deformation can characterize the beginning of the process of destruction, and may be considered as a new mechanical property for a given material.—V. G.

The Dynamic Yielding of Mild Steel. J. D. Campbell. (*Acta Met.*, 1953, **1,** Nov., 706–710). Results of dynamic and impact tests on mild steel are reviewed, and a criterion for dynamic yield is proposed based on Cottrell and Bilby's theory of yielding. The criterion is applied to some of the published experimental data and a comparison is made with theory.

A Method to Determine the Residual Stresses in Hollow Metal Cylinders without Knowing the Elastic Modulus of the Material. H. Bühler and W. Schreiber. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct., (12), 557–559). Previous methods of determining the internal stresses require a constant elastic modulus for the material. This criterion is not obeyed for cast iron and other industrially important materials. A mathematical technique is proposed for determining the internal stress distribution in a material with varying elastic modulus. These proposals have been tested experimentally and found to be satisfactory.—R. J. W.

Simplified Measurement of Internal Stress in Cylindrical Metal Bodies. H. Bühler. (*Giesserei Technisch-Wissenschaftliche Beihefte*, 1953, Oct., (12), 553–556). The equilibrium conditions for a system of internal stresses in a metal cylinder are first cited and the influence of end surfaces and specimen length on the size and distribution of these stresses is discussed. If the length/diameter ratio is greater than 6, the boring method of determining the internal stress distribution can be employed using micrometer calipers. Experimental results obtained with this simple apparatus are presented, and the usefulness of the method is discussed.

Nomogram for the Determination of the Stress Pattern in Pure Bending, for Materials with Linear Increases in Strength. R. Böklen. (*Z. Metallkunde*, 1953, **44,** Aug., 382–386). In the case of materials with similar tensile and compression properties, whose flow curves up to 1% elongation can be represented approximately by three straight lines, it is shown that the stress distribution on application and releasing of the load can be represented by a nomogram. From this it is possible to read off residual stresses without calculation. Some applications of the method are given.—L. D. H.

Photoelasticity—A Precision Instrument of Stress Analysis. M. M. Frocht, R. Guernsey, jun., and D. Landsberg. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 105–112). It is shown that the photoelastic method for the determination of factors of stress concentration in two-dimensional models, has now been developed to the point of a precision instrument in which the errors do not exceed 2%. This fact is demonstrated by checks of Howland's theoretical solution for a tension bar with a circular hole, and Neuber's and Chih-Bing Ling's solutions for the notched tension bar. Chih-Bing Ling's solution is questioned.—P. M. C.

Self-Temperature-Compensating SR-4 Strain Gages. R. S. Barker. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 119–128). Searching tests have been carried out to obtain complete data on the behaviour of a new type of SR-4 gauge, in which a change in length due to a change in temperature of the piece to which the gauge is cemented produces practically no change in resistance. The gauge is sensitive only to length changes produced by stress. The particular tests described were carried out with type EBD–3D gauges of 120 ohms resitance and $\frac{13}{16}$ in. long, cemented to tension bars of aluminium alloys 14S–T6 and 75S–T6. The deviation from the room temperature strain reading over the temperature range 60 to 280° F. was not more than ± 20 microinches/in.

The Effect of Load and Initial Shape on Location of Inflection Points of Fixed-Ended Columns. B. F. Goldhammer. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 129–136). A theoretical analysis is presented of the influence of load, original shape, and amount of original eccentricity on the location of the inflection points in compression members with fixed ends. The original shapes $y_0 = a \sin \frac{\pi x}{l}$, $y_0 = a \sin \frac{2\pi x}{l}$, and $y_0 = a\,[1+\sin \frac{2\pi}{l}\,(x-\frac{1}{4})]$ are considered. It is found that the location of inflection points varies with load. Conclusions are reached concerning what experimental values can be properly used in the determination of the effective lengths of such columns.—P. M. C.

Use of Brittle Coating Data in Stress Analysis. A. J. Durelli and C. H. Tsao. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 181–196). It is stated that a brittle coating may fail following different laws of failure, according to the coating type and loading conditions. The authors develop methods for determining both principal stresses from coating data alone for any specified law of failure. An analysis of patterns obtained by the refrigeration method is also made.

A New Electric Resistance Strain Gauge for Large Strains. N. L. Svensson. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 197–202). This note deals with the development of a new type of unbonded electrical resistance strain gauge which can be designed to measure strains up to 10%, and yet be in a position to measure the elastic strains resulting from unloading the specimen. The design is based on a lever principle, which simply transmits a reduced strain to two preloaded Nichrome wires.—P. M. C.

Two Machines for Combined Bending and Torsion Fatigue. W. N. Findley and W. I. Mitchell. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11,** (1), 203–212). The design and features of apparatus to convert Krouse plate-bending fatigue machines and Sonntag vibratory fatigue machines for use in tests under combined bending and torsion are described. The Krouse machine was provided with a mechanism (based on a stiffness measurement of the specimen) for stopping the machine when a crack of predetermined severity developed. The results are claimed to be less influenced by the period of propagation of the cracks, and improved consistency of results is illustrated by tests on an aluminium alloy and a cast iron. Especially in torsion, the stress/number-of-cycles diagrams for the cast iron were markedly changed by using this technique.—P. M. C.

Machine for Static and Dynamic Testing of Slabs. W. M. Wells, jun. and R. J. Hansen. (*Proc. Soc. Exper. Stress Anal.*, 1953, **11**, (1), 213–220). Details are given of the design and construction of a machine which will produce a controlled, uniformly applied static or impulsive load to a test panel as large as 3 ft. square and 8 in. thick. The load, which is applied to one face of the slab by helium gas pressure, may be varied from a fraction of one, to 250 lb./sq. in. The impulsive load may be applied in 0·003 sec. and may be varied in duration from a few hundredths to many seconds. Instrumentation for the measurement of pressure, deflection, acceleration, and strain has been developed. Some typical test results are presented.—P. M. C.

An Apparatus for Determining Galling Characteristics and Measuring Coefficients of Kinetic Friction. W. C. Leone and F. F. Ling. (*Proc. Exper. Stress Anal.*, 1953, **11**, (1), 239–248). The apparatus is an adaptation of a small milling machine. A flat disc of one metal is rotated with its plane vertical, whilst the end of a rod of another metal is pressed on to it horizontally. Normal and tangential forces are measured, from which coefficients of friction are determined. Test results for several metal combinations are presented.

Influence of the Condition of the Surface on the Bending Fatigue Strength. K. Wellinger and P. Gimmel. (*Metalloberfläche*, 1952, **6**, Jan., A4–A9). In tests on mild and hard carbon steels it was found that the bending fatigue strength of highly polished (metallographic) specimens was 5 to 18% lower than in the case of ground test bars. The surface microhardness after polishing 1 hr. was about 33% less than at the commencement of polishing.—L. D. H.

Surface Conditions and Mechanical Properties. H. E. Boyer. (*Steel Processing*, 1953, **39**, July, 330–334, 344 ; Aug., 383–385, 407). Fatigue strength, its importance in engineering design, and its dependence on surface condition are discussed at length. The effect of various metallic plating treatments on the fatigue strength of heat-treated steel is reviewed, nickel plating being the only one to increase the fatigue endurance limit. Residual surface stresses are considered, and the desirability of compressive stresses in the surface layers is emphasized. The effects of heat-treatment and hardenability on residual stresses are outlined, and the improvement in fatigue strength due to carburization and nitriding is discussed.—P. M. C.

A Summary of Hardness Testing Techniques. R. H. Warring. (*Machinery Lloyd*, 1953, **25**, Nov. 14, 55–61). The basic principles of hardness testing, methods employed, and the relationship between different scales of hardness are outlined.—V. G.

Scratch Hardness Measurement with a Diamond Pyramid. T. Land and B. Sugarman. (Sheet and Strip Metal Users' Techn. Assoc. : *Metal Treat. and Drop Forg.*, 1953, **20**, Oct., 464–466). Experiments are described in which scratch width has been used as a measure of the hardness of a metal. It is shown that if carefully selected diamonds are used, reproducible results can be obtained which are independent of the load applied to the diamond. An expression for the hardness is given as $5W/(d+\alpha)^2$ which gives results for steels almost identical with the Vickers indentation hardness. W = load, d = width of scratch, and α is a constant depending on the diamond (very small, and can be omitted for high loads). Results on hard chromium were highly anomalous.—P. M. C.

Practical Aspects of Hardness Testing of Steel Strip. A. G. Molinder. (*J. Iron Steel Inst.*, 1954, **177**, May, 159–164). Indentation hardness testing on the surface of steel strip is generally more or less inaccurate because of insufficient thickness of the strip, and decarburization or other structural changes in the surface layer. To determine the real hardness of steel strip a cross-section of the strip must be prepared and the indentation made on that section. The only method that is applicable to such testing is the Vickers, or similar methods, using fairly low loads and having a high precision of aim. Tensile testing, an indirect method for obtaining accurate hardness values, is limited to material of a hardness lower than about 650 D.P.N. The Rockwell methods of testing hardened steel strip, not as accurate as the others, can generally only be used on the flat surface of the strip and not on a cross-section.

Survey of Investigations of Effect of Specimen Thickness on Rockwell Tests. R. H. Heyer and V. E. Lysaght. (*Bull. Amer. Soc. Test. Mat.*, 1953, Oct., 32–39). A survey of important work, both published and unpublished, concerning the limiting thickness in Rockwell testing, is presented. It is important to note that since different workers perform hardness tests for different reasons, a limiting value of the test specimen which is suitable for one purpose may not be suitable for another.—B. G. B.

Correlation of Published Data for Correction of Rockwell Diamond Penetrator Hardness Tests on Cylindrical Specimens. R. S. Sutton and R. H. Heyer. (*Bull. Soc. Amer. Test. Mat.*, 1953, Oct., 40–41). Rockwell hardness values obtained on cylindrical surfaces are lower than on flat surfaces because the resistance to penetration is reduced by the curvature. A survey of published data concerning the correction for this effect is presented.—B. G. B.

A Miniature Hardness Tester of Czechoslovakian Construction. J. Dobrý. (*Hutnické Listy*, 1953, **8**, (6), 301–303). [In Czech]. A description is given of a hardness tester 20 in. long, weighing 3 lb., suitable for measuring Vicker's and Brinell hardness.—P. F.

Transverse Mechanical Properties of Slack-Quenched and Tempered Wrought Steel. J. Vajda and P. E. Busby. (*Amer. Soc. Metals Preprint No.* 9, 1953). A method is presented for developing reproducible slack-quenched structures (tempering by the residual heat) in heavy steel sections so that transverse mechanical properties obtained after the quench and temper may be directly associated with hardenability data. The method is applied to several steel compositions to indicate the separate and combined effects of boron and rare-earth additions on tensile and impact properties. The influence of degree of slack quenching on the transition temperature in the impact test is examined. Cooling-rate data are provided so that the structures produced on continuous cooling may be associated with particular cooling rates.

Static Load Carrying Capacity of Steels: Effect of Heat Treatment. R. G. B. Yeo and T. Ko. (*Iron Steel*, 1953, **26**, Nov., 498–500). The authors have investigated the effect of heat-treatment conditions on the static load-carrying capacity of a through-hardened carbon steel and of a carburized Krupp steel. The effect of hardness of the carbon steel is considered, and, on the carburized steel, the factors studied are case thickness, hardness variation due to tempering and to the presence of retained austenite, and pre-quenching treatment. The results are presented graphically and are discussed in relation to Palmgren's equation.—G. F.

The End-Quench Hardenability of Different Common Structural Steels. H. Kiessler and K. Schweyher. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 475–481). The spread of end-quench hardness curves has been studied by taking samples from different places in an ingot and from different ingots in a heat. The spread amounts to no more than two Rockwell C units, at least up to 50 mm. from the quenched end. The curves determined for a number of common heat-treating and special steels are presented and compared with the Jominy hardness bands of corresponding American standard steels. From individual curves of different heats of the same steel, mean hardness curves were derived to characterize the hardenability. No relationship was found between hardenability and McQuaid-Ehn grain size.—J. P.

Depth Hardenability of Argentinian Silicon–Manganese Spring Steels. C. A. Carreras. (*Ing. e Industr.*, 1953, **21**, May, 109–114 ; July, 91–95 ; Sept., 82–84). [In Spanish]. The author discusses the McQuaid-Ehn method of determining grain size and points out the importance of grain size determinations in forecasting the behaviour of the steel under heat-treatment and mechanical working. The Jominy test is dealt with and data relating to critical diameters and various determinations for the 50% martensite zone are given.—R. S.

The Dependence of the Steep Fall in the Impact Strength after Ageing on the Chemical Composition of Rimming Steels. H. Kornfeld. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 469–474). Curves of impact strength after ageing, using samples from the rim of billets, as a function of temperature have been employed to derive a mathematical expression relating the mean impact strength to temperature of test, amount of deformation and contents of phosphorus, nitrogen, and oxygen.—J. P.

The Strain-Ageing of Mild Steel: A Critical Investigation into the Ageing of Mild-Steel Strip after Temper-Rolling. B. Jones and R. A. Owen-Barnett. (*J. Iron Steel Inst.*, 1954, **177**, June, 209–220). [This issue].

The Effect of Boron on Notch Toughness and Temper Embrittlement. A. E. Powers and R. G. Carlson. (*Amer. Soc. Metals, Preprint No.* 21, 1953). Isothermal embrittlement curves have been constructed for two manganese steels having an identical base composition, but differing in that one of the steels contained 0·0034% boron whilst the other was free from boron. Susceptibility to reversible temper embrittlement at temperatures between 850° and 1050° F. was increased by the boron addition. For all other tempering treatments which avoid reversible temper embrittlement, the two steels have reasonably identical notch-bar toughness. Classification for various forms of embrittlement arising during tempering is discussed.—J. R. P.

A Theory of Hydrogen Embrittlement. F. de Kazinczy. (*J. Iron Steel Inst.*, 1954, **177,** May, 85–92). Hydrogen embrittlement is caused by a lowering of shear strength and cleavage strength. This can be explained by assuming that molecular hydrogen of high pressure is included in a Griffith crack or some other crack, which initiates fracturing. During crack spreading the gas expands and releases energy, which results in a lowering of the fracture stress. It is shown that hydrogen diffusion into the crack is needed during crack spreading, by which the time and temperature effect of hydrogen embrittlement can be explained.

Some Effects of Microstructure Upon Temper Brittleness. D. C. Buffum and L. D. Jaffe. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5,** Oct., 1373–1374). The effects of microstructure on temper brittleness in SAE–3140 steel has been studied on heat-treated $\frac{5}{8}$-in. round bars tested over a range of temperatures on a Charpy machine. Pearlite and ferrite formed isothermally show no significant temper brittleness during their formation, and for a fixed embrittling treatment, less temper brittleness develops in pearlite and pro-eutectoid ferrite than in tempered martensite of the same composition.—G. F.

The Influence of Manganese, Nickel, and Vanadium in Conjunction with Carbon on the Abrasion Behaviour of Normalized Steels. H. Arend. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 529–533). Abrasion tests carried out on a Spindel machine show that in normalized steels, carbon is chiefly responsible for wear resistance. In vanadium steels, only the carbon not combined with the vanadium is active in this respect. Tests show that wear is independent of surface pressure at testing speeds of approximately 1 m./sec. Comparison of results from a manganese and a nickel steel with about the same carbon content and the same alloying addition shows the marked effect of manganese. Up to a hardness of 300 Brinell, wear decreases with hardness ; at hardnesses greater than 300, vanadium steels are superior, whereas below this hardness, manganese steels are to be preferred.

Oxidic Permanent Magnets from Barium Oxide and Ferric Oxide. H. Fahlenbrach and W. Heister. (*Arch. Eisenhüttenwesen*, 1953, **25,** Nov.-Dec., 523–528). The development and magnetic properties of permanent magnet material of the chemical composition $BaO.6Fe_2O_3$ are described. It has been possible to produce magnets in this material with BH_{max} values approximately the same as those of AlNi 120. A further development consists of orientating the powder grains before and during the pressing process and so obtaining a large increase in the value of BH_{max}. As compared with AlNi and AlNiCo magnets, the barium-oxide/ferric-oxide material suffers from a large temperature coefficient and a greater brittleness.—J. P.

Metallic Wear Measured by Radio-Isotopes. (*Metal Treat. and Drop Forg.*, 1953, **20,** Sept., 425, 426). Brief details are given of the use of radioactive isotopes in the measurement of wear in internal combustion engines. Experiments are being carried out by Shell-Mex and British Petroleum companies on a 5-h.p. single-cylinder diesel engine which is fitted with a top cast-iron piston ring previously irradiated in the atomic pile at Harwell. Continuous measurements are made of the radioactivity of the crankcase oil, which is an indication of the transfer of material from the piston ring to the oil.—P. M. C.

Magnetic Properties of the Nickel-Iron Alloys. (*Nickel Bull.*, 1953, **26,** May, 74, 75). In this brief note, the fundamental properties (intrinsic saturation, resistivity, and initial permeability) are plotted for the iron-nickel series. The many materials developed from this series can be conveniently divided into three main classes containing approximately 78, 50 and 35% of nickel. The first of these is characterized by the highest permeability but with a relatively low saturation value ; the other two have increased saturation and resistivity respectively, whilst still maintaining relatively high permeabilities. Special properties have also been induced in certain alloys by orientation of structure. Data on magnetic and mechanical properties are presented in tabular form for British alloys of each type.—P. M. C.

High Magnetic Permeability Steels in the Design of Electrical Machinery. A. Rolla. (*Ing. Mecc.*, 1953, **2,** Sept., 17–22). [In Italian]. In the construction of electric machines components often have to be of steel with high magnetic permeability and with good mechanical properties. The author shows how the addition of all alloying elements causes a loss in the magnetic properties of iron, with the exception of nickel, which has no effect, and cobalt which actually improves the magnetic properties. A good combination of magnetic and mechanical properties can be obtained by small additions of molybdenum (0·25–0·50%) to nickel steels (0·5–3·0% Ni.) These steels, however, must be normalized (at 870° C.) and tempered (at 630° C.) before use.

How Heat-Treatment Affects Properties of Cold Worked 18-8 Wire. S. Storcheim. (*Iron Age*, 1953, **172,** Oct. 1, 112–114). A sudden and large increase in magnetic remanence with relatively no change in coercive force has been observed for severely cold worked 18/8 stainless steel wire at 1150° F. At temperatures above this figure the remanence again dropped and the coercive force rose until a magnetic condition was reached at 1400° F. It was also noted that at 1000° F. stress relief occurred, this being shown by the opening of the curl diameter of the wire.—A. M. F.

The Electrical Conductivity of Wüstite Melts. H. Inouye, J. W. Tomlinson and J. Chipman. (*Trans. Faraday Soc.*, 1953, **49,** July, 796–801). The specific conductance of molten iron oxide between iron electrodes has been measured and the results are given and discussed. The influence of MnO, CaO, TiO_2, Al_2O_3 and SiO_2 on the conductivity was also determined.

The Surface Free Energy of a Metal. I—Normal State. II—Superconducting State. R. Stratton. (*Phil. Mag.*, 1953, **44,** Nov., 1236–1258).

Solution Calorimeter for the Accurate Determination of Heats of Solution and Formation. F. E. Wittig. (*Z. Metallkunde*, 1953, **44,** Sept., 427–431). The construction and mode of operation of a solution calorimeter is described, for temperatures between 20° and 40° C. The apparatus is standardized electrically, and an accuracy of measurement of 0·1% has been attained.—L. D. H.

The Melting of Iron at High Pressures. F. E. Simon. (*Nature*, 1953, **172,** Oct. 24, 746–747). The semi-empirical formula $p/\alpha = (T/T_0)^c - 1$, where a is related to the internal pressure and c is a numerical constant, has recently been given a theoretical foundation. Also, data on the heat of fusion and volume change of iron at the normal melting point now permit the constants to be evaluated. Values of $c = 4$ and $\alpha = 150{,}000$ are given. The assumptions involved are outlined and the equation is applied to the internal condition of the earth.—A. G.

On the Activities of Co-Existent Elements in Molten Iron. I.—The Activity of Carbon in Molten Iron. K. Sanbongi and M. Ohtani. (*Tetsu to Hagane*, 1953, **39,** May, 483–487). [In Japanese]. Activities of carbon at 1450, 1500, and 1550° C. were obtained from measurements on a specially constructed concentration cell. The activity is approximately equal to the molar fraction up to 1% C; it then increases rapidly. The results are applied to the Fe–C–O system. (16 references).

Sound Waves Uncover Inner Flaws. (*Steel*, 1953, **133,** Dec. 14, 120–121). The use made by the Douglas Aircraft Co. of ultrasonics for testing materials and fabricated parts is described. Examples include examining for flaws in forgings, extruded shapes, and heavy sections. The immersion method is used where possible which saves the machining surfaces for scanning.—D. L. C. P.

Applications of Ultrasonic Inspections. A. Barath. (*Non-Destructive Test.*, 1953, **11,** Sept., 27–31). The author reviews ultrasonic inspection techniques as used at Douglas Aircraft Co. California. Particular attention is given to the immersed scanning technique which is of special use when testing irregularly shaped components.—P. M. C.

Some Applications of High Power Ultrasonics in the Metal Industries. E. A. Neppiras. (*Metal Treatment and Drop Forg.*, 1953, **20,** Sept., 391–398). The author discusses the several uses, (and techniques employed), of intense ultrasonic vibrations in the metallurgical field. These include fatigue

and wear tests, the machining of brittle metals, the acceleration of surface-gas reactions, the removal of surface impurities (by cavitation), the refinement of grain structure during ingot solidification, the degasification of molten metals, and the increase in rates of solution of solids in liquids. (32 references).

Experiments on the Ultrasonic Testing of Cast Iron. H. J. Seemann. (*Giesserei, Technisch-Wissenschaftliche Beihefte*, 1952, Sept., 403–408). The fundamentals of both the echo method and the penetration method of ultrasonic testing are described. Experiments are described wherein the effect of texture and composition on the ultrasonic waves were investigated. The ultrasonic behaviour of cast iron depends markedly on the amount and form of graphite distribution. With increasing graphite content (which leads to larger graphite particles) the permeability of cast iron to ultrasonic waves is reduced; the velocity of the waves is also reduced.—R. J. W.

Ultrasonic Testing of Forgings and Castings. V. Blažek, J. Koblovský, J. Gumanskij, P. Schier, and K. Slonek. (*Strojírenství*, 1953, **3**, (10), 744–751). [In Czech]. An account is given of the use of ultrasonic equipment of the transmission-type "Ultrasonel" (Belgian) and of the reflection-type "Hughes II B" (British) in Czechoslovak heavy industry, and of research on the use of ultrasonics for detecting flaws in castings and forgings, carried out in Czechoslovakia. Flaws as revealed on the cathode-ray screens are shown and analysed. Comparative tests, using both types of detector, showed that in the case of heat-treated pieces with machined surfaces the reflection detector gave the most accurate information as to size and position of defects, whilst the transmission method was more advantageously used with steel and iron castings.

Ultrasonic Testing of a Large Engine Crankshaft. W. A. Black. (*Yearbook Amer. Iron Steel Inst.*, 1953, 235–253). The author discusses the value of non-destructive testing, referring particularly to ultrasonic testing. He describes in detail the ultrasonic testing of a large engine crankshaft which revealed extensive and dangerous cracks in one of the pins, in a position undetectable by visual or other surface inspection.—G. F.

Handling Equipment and Safety Containers for Use with Isotope X-Ray Sources for Industrial Radiography. D. R. Allen, H. S. Peiser, and J. R. Rait. (*Brit. J. App. Phys.*, 1953, **4**, Sept., 268–273). The design and construction of a complete set of handling equipment for radioactive materials, including container, and transfer and sighting devices, is described.—J. O. L.

Economic Points of View in the Non-Destructive Testing of Materials. F. Förster. (*Z. Metallkunde*, 1953, **44**, Aug., 346–352). The author first deals with the nature and range of application of non-destructive tests, and indicates their economic advantages. Examples of methods adopted are then described, including automatic sorting, and testing of materials during manufacture and in use. The application of statistical treatment is outlined.—L. D. H.

Non-Destructive Testing of Brown Boveri Products by Gamma Radiography. A. Lüthy. (*Brown Boveri Rev.*, 1953, **40**, Aug., 296–304). The advantages of artificial radioactive isotopes in gamma radiography are indicated; the properties of the commonly used sources are described, and examples of their application to the detection of faults in cast and welded parts are given.—L. D. H.

Non-Destructive Testing Methods. C. C. Gee. (*Steam Eng.*, 1953, **22**, Sept., 447–451; **23**, Oct., 6–10; Nov. 61–65; Dec., 107–111; 1954, Jan., 135–139; Feb., 187–192). Continuation of a series of articles *see J. Iron Steel Inst.*, 1953, **176**, Feb., 238). In each part the principles of the methods under consideration are outlined and their application to industrial practice briefly discussed. Particular attention is paid to the use of the various methods of testing boiler drums, welds, and steel plates. The techniques discussed are as follows: Part III, radiography using X-rays, γ-rays and the high-voltage radiation from betatrons and linear accelerators; Part IV, sonic and ultrasonic methods of internal flow detection; Part V, magnetic and electrical methods of inspection (other than crack detection); Part VI, X-ray and electron diffraction methods, spectrographic analysis, spot tests and the electrographic technique; Part VII, the use of the various types of strain gauges, and the detection and measurement of vibration; Part VIII, microhardness, the measurement of elastic constants, the measurement of thickness by magnetic, electrical and ultrasonic methods, and the measurement of thickness using γ and β radiation.—B. C. W.

The Art of Radiography. N. C. Miller. (*Non-Destructive Test.*, 1953, **11**, Sept., 11–15). The author discusses the radiographer's equipment, background, and training, and describes several unorthodox techniques, which, coupled with resourcefulness and imagination, can extend the usefulness of radiography as an inspection process. Unconventional geometry, high precision, and thickness compensation are discussed.—P. M. C.

Report on the Investigation of Betratron Radiographic Techniques. C. J. Smith. (*Non-Destructive Test.*, 1953, **11**, Sept., 17–22). The results of experiments using the 22MeV. betatron beam at the Los Alamos Scientific Laboratory are discussed. The investigation gave data on the protection of film from scattered radiation, the comparative effect of lead front and back screens on film density, the relative merits of various materials when used as intensifying screens, the design of lead cones for beam intensity equalization, and the effect of the vertical alignment of the betatron tube on the pin-hole image obtained.—P. M. C.

Gamma Radiography with "Pantatron". (*Non-Destructive Test.*, 1953, **11**, Sept., 23–25). Handling and control equipment for use with radio-isotopes is described and illustrated. The makers are Panta Instruments, London. An isotope source can be transferred to any desired location, up to 60 ft. away from its container, by passing along a flexible tube. The control of this movement is effected from up to 30 ft. away from the container.—P. M. C.

Properties of Some Radioactive Isotopes Useful in Radiography. J. Kohl. (*Non-Destructive Test.*, 1953, **11**, Sept., 33–37). The basic differences between the continuous energy distribution from X-ray tubes and the limited number of energies at which radio-isotopes emit gamma rays are illustrated, and the relative penetrations of alpha, beta, and gamma radiations are given in terms of thicknesses of steel and aluminium. The radiographic properties (half-life, end product, energy spectrum, shielding, radiation, useful range of penetration in steel) are discussed for iridium$_{192}$, cesium$_{137}$, radium, and cobalt$_{60}$. (12 references).—P. M. C.

Radiography in a Clyde Shipyard. E. J. Duffy. (*Trans. Inst. Eng. Ship Scotland*, 1952–53, **96**, 34–70). The function of the radiographic inspection unit of a Clyde shipyard is explained. Recent developments in the field of radiographic inspection due to the availability of artificially produced radioactive isotopes are discussed and a comparison is drawn between the results obtained using X-rays and gamma rays with particular reference to $\frac{1}{2}$ in. and $1\frac{1}{2}$ in. plate thickness.

Use of Gamma-Ray Emitters for Industrial Radiography. H. R. Isenburger. (*Amer. Foundryman*, 1953, **24**, Dec., 46–48). This is a short account of the use of radioactive isotopes in industrial radiography. Brief reference is made to a new technique which, compared with the lead foil and medium-speed no-screen film method, enables the exposures to be considerably reduced; the method requires a special filter set and a tungstate screen. A table of useful γ-ray emitters is given.—B. C. W

Measuring Wall Thickness of Gas Cylinders during Manufacture. F. Bollenrath and V. Hauk. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 515–518). An apparatus is described in which the radiation from a fixed X-ray tube passes through the wall of a gas cylinder and falls on a counter held within the clylinder. The output from this counter is opposed to that from a compensating counter and the net signal amplified and recorded on a moving paper chart. The cylinder is rotated and moved vertically between the X-ray tube and the counter, and in this way the whole cylinder is examined automatically.—J. P.

Electromagnetic Induction Tests and Magnetic Flaw Detection Help Metallurgical Industry. B. Šesták. (*Hutnické Listy*, 1953, **8**, (7), 346–349; (8), 409–411). [In Czech]. The principles of electromagnetic sorting methods are explained and factors influencing results are discussed. A Czechoslovakian instrument for the magnetic sorting of ferrous materials is described with examples of its application.—P. F.

Investigation of Heat-Resisting Steel for Gas Turbines (I). S. Koshiba and T. Kuno. (*Tetsu to Hagane*, 1953, **39**, June, 609–614). [In Japanese]. Studies were made of the effects of carbon, silicon, manganese, and nickel contents on the ageing of 15/20 Ni–Cr austenitic heat-resisting steel, and of changes in hardness due to different heat-treatments. Optimum compositions, and solution and ageing treatments, were determined.—K. E. J.

Metallurgical Aspects of High Temperature Steam and Gas Turbine Plants. J. M. Robertson. (*North-East Coast Inst. Engineers and Shipbuilders, Advance Copy*, Jan. 15, 1954). The properties of metals used at temperatures above 850° F., *i.e.*, resistance to creep, rupture, high-temperature fatigue, relaxation, thermal shock, and high temperature corrosion, are reviewed. The composition, treatment and properties of non-stainless ferritic steels, stainless ferritic steels, austenitic steels, and alloys based on nickel and cobalt, as well as some aspects of welding relevant to high-temperature applications are discussed.—V. G.

The Development of Heat-Resisting Steel with High Strength at Elevated Temperatures. K. Bungardt. (*Stahl u. Eisen*, 1953, **73**, Nov. 5, 1496–1503: *Iron Steel Inst. Translation Series No.* 483, 1953). The development of heat-resisting steels is surveyed and the metallurgical aspects related to creep behaviour are illustrated by examples. Molybdenum additions are particularly important in reducing creep rate. Precipitations and other insoluble constituents (*e.g.*, carbides, nitrides, intermetallic compounds) generally increase creep resistance, by an amount depending on their nature, shape, size, and distribution. The question, which heat-treated condition is the most favourable for creep resistance, can be assessed only by considering the relevant stress conditions. Recovery and recrystallization can be controlling factors in creep. Frequently cold deformation is used to improve creep resistance, which increases as grain size becomes smaller. Adequate corrosion resistance is an essential for the application of heat-resisting steels. The requirements of satisfactory scaling resistance are generally met by a chromium content of 12 to 20%. Premature failures in some instances can be attributed to rapid oxidation induced by vanadium pentoxide in the ash from burnt fuel.—J. P.

Heat-Resisting Materials and Cermets. B. Waeser. (*Werkstoffe u. Korrosion*, 1953, **4**, Nov., 397–399). This is a general review of modern heat-resisting materials with 28 references. Three main groups are considered: Alloy layer coatings produced by diffusion, as in the chromizing processes; special heat-resisting alloys; and the newest types of material, the "cermets," which combine the heat-resistance of ceramics with the toughness and elasticity of metals.—J. C. H.

Heat-Resisting Materials for Aviation Gas Turbines. N. Abe and Y. Ikeda. (*Tetsu to Hagane*, 1953, **39**, May, 550–558). [In Japanese]. Analyses, properties, and other data are given for about 40 ferrous and non-ferrous heat-resisting alloys.

Studies of the Heat-Resisting Alloy (IV). E. Asano. (*Tetsu to Hagane*, 1953, **39**, May, 531–536). [In Japanese]. Results are reported from studies on Timken 16–25–6 Cr–Ni–Mo alloy to investigate recrystallization and the change of strain introduced by cold-working during tempering. Effects of nitrogen, and of varying molybdenum content, are also reported.—K. E. J.

The Substitution of Manganese for Nickel in 16–25–6 Alloy. W. E. Ellis and M. Fleischmann. (*Amer. Soc. Met. Preprint No.* 11w, 1953). The investigation covers the room temperature mechanical properties, with and without cold work, precipitation hardening data, and microstructural characteristics of a modified iron alloy containing 16% Cr, 25% Ni, and 6% Mo in which 10% of the nickel is replaced by 6% Mn. Limited stress-rupture data in the 595–760° C. range are given.—J. C. B.

Work Softening of 16–25–6 Alloy at Elevated Temperatures. D. A. J. Millar and J. Wulff. (*Amer. Soc. Met. Preprint No.* 12w, 1953). True-stress/true-strain curves are presented for the Timken iron alloy with 16% Cr, 25% Ni, 6% Mo, tested in tension and at elevated temperatures. These curves display 'strain softening' of the material. Interrupting the deformation is shown to result in increased strength by ageing. It is postulated that strain-induced solution of grain boundary precipitates is responsible for the softening, and that re-precipitation on deformation planes causes the increase in strength on ageing. Metallographic evidence is presented to support this hypothesis, and some possible mechanisms to account for the solution effect of deformation are discussed.

Progress in Stainless and Heat Resisting Materials. J. Lomas. (*Eng. Boiler House Rev.*, 1953, **68**, Oct., 310–312). The lines along which stainless and heat-resisting steels have been developed in the last 12 months have largely been a continuation of earlier trends. Much new information, concerning boiler house applications in particular, is surveyed.

Creep and Recovery in Metals. A. J. Kennedy. (*Brit. J. App. Phys.*, 1953, **4**, Aug., 225–233). A review of experimental evidence on the nature of creep and recovery mechanisms in single and polycrystalline metallic structures lends to consideration of the character of creep when intermittent reduction of stress occurs. At high stresses and temperatures such conditions are of importance in structural and mechanical engineering. (126 references).—J. O. L.

Tensile and Impact Properties of Fe–Si, Fe–Ni, Fe–Cr, and Fe–Mo Alloys of High Purity. W. P. Rees, B. E. Hopkins, and H. R. Tipler. (*J. Iron Steel Inst.*, 1954, **177**, May, 93–110). The tensile and impact properties of normalized high-purity iron–silicon, iron–nickel, iron–chromium, and iron–molybdenum alloys at various temperatures covering the tough-to-brittle transition are discussed. The low brittle-fracture strengths and the high transition temperatures in the iron–silicon alloys are attributed largely to intergranular brittleness; the considerable increase in silicon content is presumably due mainly to the large rise in yield stress, since there was little change in the brittle strength. Refining the grain size of a 1% silicon–iron alloy eliminated failure at grain boundaries and resulted in a considerable fall in transition temperature compared with that of iron. The effect of nickel on high-purity iron in the brittle range is shown to be affected by the two factors, the occurrence of grain-boundary weakness in alloys containing 2% nickel and above, and the formation to some extent of α_2 structure. The brittle behaviour of iron–nickel alloys is sensitive to small amounts of certain elements such as carbon and oxygen, and the influence of nickel in accentuating the embrittling effect of oxygen is suggested as a cause for the occurrence of intergranular weakness in alloys with 2% of nickel and above. Evidence is given to show that the brittle strength of the iron–nickel alloys probably decreases with rise in temperature. Chromium and molybdenum were found to have only a small effect in reducing the impact transition temperature of high-purity iron. A comparison is made of the influence of silicon, nickel, chromium, molybdenum, and manganese on the strength of high-purity iron in the ductile condition, and the strengthening effect of these elements for given weight percentages increases in the order chromium, molybdenum, nickel, manganese, silicon. A number of factors that may be involved in the strengthening produced by elements in solid solution are discussed, and it is suggested that a more precise knowledge of the particular type of lattice distortion involved is required before the factors responsible for the strengthening effect can be elucidated. It is emphasized that the softening effect of the first additions of chromium to iron now seems to be well established; such effects need accounting for in any theory of the strengths of solid solutions.

Metallurgical Aspects of the Development of Small Gas Turbines. W. L. Slosson. (*J. Met.*, 1953, **5**, Nov., 1419–1426). As an aid towards better understanding of the metallurgical problems involved, the author describes the development, construction, and operation principles of a small gas turbine produced by the Boeing Airplane Co. for industrial and military use. A basic operation diagram outlining airflow, operating temperatures, and component speeds is shown and the choice of alloys for the various components is discussed.—G. F.

New Alloy—Boost to Turbines, Relief for Stockpile. A. G. Gray. (*Steel*, 1953, **133**, Dec. 28, 68–70). A new alloy developed and produced by Timken Roller Bearing Co. as a modification of their alloy steel 16/25/6 Cr–Ni–Mo is suitable for use on turbine wheels. In the new alloy, to compensate for this reduction, manganese has been increased from 2% to 7%, carbon maximum reduced from 0·12% to 0·08% and nitrogen increased from 0·10–0·20% to 0·15–0·25%. High-temperature strength is maintained and ductility improved.

Current Research on Heat Resistant Cast Alloys as Related to Nickel Conservation. E. A. Schoefer. (*Indust. Heating*, 1953, **20**, Oct., 1973–1982, 2108–2113). The characteristics of a range of alloys have been studied. An alloy with 21% Cr and 9% Ni was found to have corrosion resistance comparable to the higher-nickel types up to 1600° F. The susceptibility of 25%-Cr 20%-Ni alloys to sigma phase formation is being investigated. Heat-treatment of 35%-Ni 15%-Cr alloys to improve carbide distribution improved the fatigue resistance.

Ceramic Materials for the Construction of Engineering Parts. B. L. Majumder. (*Ceramics*, 1953, **5**, Sept., 314–320). The author examines the properties of ceramic and metal-ceramic

materials (cermets) with a view to assessing their value, for use as high-duty, high-temperature parts in gas turbines and jet engines. (36 references).—D. L. C. P.

Comparative High-Temperature Properties of British and American Steels. W. E. Bardgett and C. L. Clark. (*Inst. Mech. Eng., Preprint*, Feb. 4, 1954). Five representative high-temperature steels have been creep tested for a minimum of 1000 hr. in the laboratories of the United Steel Co., Rotherham, and the Timken Roller Bearing Co., Ohio. Specimens of each steel were supplied by each company, the alloying elements in the types being : 0·5% Mo ; 2·25% Cr, 1% Mo ; 5% Cr, Mo+Ti ; 18% Cr, 12% Ni+Cb ; 25% Cr, 12% Ni. Full details are given of compositions and test results. A high degree of reproducibility was shown by the test data for the two laboratories on the three ferritic steels but those on the austenitic steels showed substantial differences. Only two of the British steels, both ferritic, showed similar creep behaviour compared with the corresponding American steels, the remaining three being appreciably different.—P. M. C.

New Creep Resistant Ferritic Steels. D. D. Howat. (*Mat. Methods*, 1953, **38**, Sept., 87–90). The author reviews recent progress made in Britain in the development of ferritic steels for gas turbine applications. Modified 10–12% chromium steels are discussed, and the work in this field of several English investigators is reviewed.—P. M. C.

Temperature Control by Means of a Dilatometric Controller in Tests on Steels at Elevated Temperatures. J. Stejspal. (*Hutnické Listy*, 1953, **8**, (4), 175–178). [In Czech]. A dilatometric temperature controller for use in creep testing is described.—P. F.

A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures. R. W. Bailey. (*Inst. Mech. Eng., Preprint*, Feb. 4, 1954). The author examines the more commonly used procedures for utilizing creep test results, and focuses attention on factors which introduce uncertainty in the predicted service behaviour. The principal disturbing factor is thermal action, and the method of extrapolation beyond the test times is next in importance. Both factors are examined in detail, and the author concludes that satisfactory comparisons of working stress using different procedures cannot at present be made. (10 references).—P. M. C.

The Design of Creep-Resisting Steels. E. W. Colbeck, J. R. Rait, and J. O. Ward. (British Assoc.: *Engineering*, 1953, **176**, Oct. 16, 505–506; Oct. 23, 537–540). After reviewing early studies of creep in metals, the authors refer to theoretical work on creep and to the properties commonly required in high-temperature materials—mechanical, chemical, physical, and other properties are discussed. Types of alloys for high-temperature service are described and the constitution of creep-resisting quench-hardening alloys is examined. (28 references).—M. D. J. B.

Constant Stress Systems. A. J. Kennedy. (*Instrument Practice*, 1953, **7**, Sept., 879–887). A general survey is made of methods employed in applying a constant stress to creep test specimens. The systems are described under two general headings: (1) Profile devices, in which a three- or two-dimensional system is designed from a calculated curve, and geometrical devices. The theoretical basis for each of 14 systems is given, and economic and other factors are shown to influence the choice of a particular system.—L. D. H.

On the Generality of the Cubic Creep Function. A. J. Kennedy. (*J. Mech. Phys. Solids*, 1953, **1**, 172–181). The fit of a cubic creep function to a wide variety of materials, including steel, is examined and the results compared with the fit to a general power law. The behaviour of a simple mechanical model, composed essentially of bi-stable units, is shown to approximate to the observed type of transient creep in real materials. A statistical approach to the problem is outlined.—J. G. W.

Researches at the Louvain Centre. R. de Strycker. (Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture (I.R.S.I.A.) : *Comptes Rendus de Recherches*, 1953, July, 61–151). The report deals with 10 years work on the creep of rods (0·75% C) for pre-stressed concrete. Full details are given of the testing methods. Thermostatic conditions are shown to be essential. The test-piece need not be longer than 200 mm. and the gauge length must be situated from 5 to 20 diameters from the grips. A variation of 10% from the mean was found in single batches of material. The creep of patented and drawn rod varies rapidly with tension but it is considered that in practice, errors on the applied tension of 15% are not dangerous. Stress variations caused by a change in temperature will cause variations in creep depending upon the maximum stress achieved. Temporary overstrain initially reduces creep and relaxation. For patented and drawn rod, creep and relaxation are approximately linear with log time, and the results of short time tests can be extrapolated without danger. This relation does not hold for hot rolled and heat-treated rod. Young's modulus is found to decrease with applied tension by a maximum of 2%. Recovery is briefly considered. Using drawn and patented wire, no creep limit can be detected under low tension, but heat-treated material shows a lower creep limit than other investigators have found.—A. D. H.

Researches at the Liége Centre. F. Campus. (Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture (I.R.S.I.A.) : *Comptes Rendus de Recherches*, 1953, July, 15–58). Creep and relaxation limits have been determined for steels containing 0·05–0·8% C, 0·3–2·0% Mn in the form of bar and wire rod using test pieces 1 m. long and 3–20 mm. in dia. under thermostatically controlled conditions. The relation of these properties to those determined in the conventional tensile test is discussed. They are shown to approximate to the limit of proportionality. Room temperature creep and relaxation of 0·75–0·85% C steels are also dealt with. Great differences were found between the steels tested and the creep curves showed marked discontinuities. The relation between creep and relaxation is discussed.

Effect of Heat-Treatment on the Brittleness of High-Purity Iron–Nitrogen Alloys. B. E. Hopkins and H. R. Tipler. (*J. Iron Steel Inst.*, 1954, 177, May, 101–107). The results of tensile and notch-impact tests on two high-purity iron–0·01%-nitrogen alloys at temperatures spanning the tough-to-brittle transition are discussed. The intergranular weakness encountered on adding nitrogen to iron may be almost entirely removed by furnace-cooling from the austenitic region, but its severity is enhanced by increasing the rate of cooling. Maximum embrittlement of the grain boundaries is developed well inside the α solid solution field at 600–700° C., water-quenching from these temperatures resulting in remarkably low brittle-fracture stresses. This extreme brittleness could be caused by grain-boundary segregation of nitrogen, which tends to be dispersed at higher and lower temperatures. There is a linear rise with temperature in the brittle-fracture stress of the material in the most brittle condition over the wide range of −196° C. to room temperature. The microstructures of the alloys after various heat-treatments are discussed in the light of recently published work.

Studies on Boron Treated Constructional Alloy Steels. (I). T. Kawai, R. Inoue, and K. Ogawa. (*Tetsu to Hagane*, 1953, **39**, June, 602–609 ; July, 716–722). [In Japanese]. The effects of boron additions on grain sizes, critical temperatures, Jominy hardenabilities, and isothermal transformations were studied with several types of constructional alloy steels. Conditions for the preparation of good heats of boron steel are specified. Correct Al–Ti–B treatment improved notch toughness of steels completely hardened and tempered at temperatures below 400° C. With incompletely hardened and tempered steel, boron additions had varying effects, according to the microstructure. The effects of intermediate transformations (austempering) were also studied.

Selecting Materials to Meet Mechanical Design Requirements. J. R. Hunt. (*Mat. Methods*, 1953, **38**, Sept., 102–107). A method is proposed, based on parameters, for determining the most economical material for any specific mechanical application. The basic characteristics, yield strength, elastic modulus, density, and cost, are considered, and performance parameters for relative dimensions, volumes, weights, and costs for equal strength and stiffness are derived and tabulated for a range of steels and non-ferrous metals and alloys.—P. M. C.

Modern Ferrous Materials for Springs. J. Lomas. (*Machinery Lloyd*, 1953, **25**, Nov. 28, 65–69). The principal modern ferrous materials for springs, their characteristics and suitability for particular purposes are outlined.—V. G.

High Carbon Wire for Prestressed Concrete. (*Aciérs Fins Spec. Franç.*, 1953, 43–46). Advantages of the use of pre-stressed concrete and the properties required of steel for this purpose are explained.—V. G.

"Desegatized" Tool Steels. (*Machinery*, 1953, **83**, Nov. 6, 906–907). The problem of carbide segregation in high-alloy

tool steels is discussed. A comparison is made between orthodox high-alloy steels and those marketed under the trade name of 'Desegatized' steels by Latrobe Steel Co., Latrobe, Pa. It shows the improved impact and high temperature qualities obtained by desegatizing and the effect on tool life.—M. A. K.

Hot Working Steels in the Forge and Their Treatment. W. Eilender and R. Mintrop. (*Steel Processing*, 1953, **39**, Oct., 509–515). A survey is made of the most frequently used hot-forging die steels and their compositions and properties. Their heat-treatment is discussed, and among the newer hardening methods, hot bath hardening and intermediate stage treating are given special emphasis. The latter is said to prolong the life of hot-forging tools.—P. M. C.

Tool Steels for Hot Working. H. M. Hiller. (*Stahl. u. Eisen*, 1953, **73**, Nov. 19, 1565–1574). This paper is devoted to tool steels for the working of hot metals or other materials and not to tools which get hot during machining. The important heat-resisting and mechanical requirements of such steels and methods for their determination are discussed. The influence of alloying elements on the characteristic properties are described. The most important hot working tool steels from the Stahl-Eisen handbook, their properties and applicability are tabulated.—J. P.

The Influence of Surface Active Substances on the Penetration of Hydrogen into Iron and the Mechanism of the Hydrogen Over-Potential. I. A. Bagotskaya and A. N. Frumkin. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **92**, (5), 979–982). [In Russian]. A study of the transfer of the hydrogen over-potential through an iron diaphragm with the simultaneous measurement of the amount of hydrogen diffused through it during cathodic polarization in solutions of pure 1*N* HCl and in the presence of an inhibitor (tetrabutylammonium sulphate with potassium bromide) is described. On additions of arsenic to the polarization cell in concentrations of $10^{-6}-10^{-4}$ *M*, with and without the inhibitor, the change of potential under the influence of the diffusing hydrogen was not observed. This result is in opposition to the views expressed in the literature that the increased diffusion of hydrogen, observed in the presence of arsenic, is due to the slower removal of hydrogen from the diaphragm surface.—V. G.

Some Experiments on the Evolution of Hydrogen from Steel. H. Shimoda, S. Onodera, and K. Yamagata. (*Tetsu to Hagane*, 1953, **39**, May, 524–531). [In Japanese]. Investigations are reported concerning hydrogen evolution from steel under laboratory conditions and in cases of fabricated parts. Stressing caused the evolution of 30–50% of the hydrogen from specimens saturated hot in the gas.—K. E. J.

Study of Some Low-Alloy Steels after Normal and Interrupted Quenching. G. Delbart and F. Maratray. (*Rev. Mét.*, 1953, **50**, Nov., 781–806). Part I describes comparative tests on Mn–Si, Cr–Mn–Si, and Cr–V steels containing 0·38–0·45% carbon after both oil and isothermal quenching. A longer tempering time at 200° C. lowers rupture strength and raises the elastic limit. Tempering at 250° C. after isothermal quenching at 200–300° C. gives maximum values of ultimate strength and elasticity, whilst tempering at 350° C. has little effect on mechanical properties. Part II deals with similar steels with 0·28–0·32% carbon and also Cr–V steels low in vanadium (0·05–0·08%). For an equal strength after oil-quenching, these steels have a lower elongation and better impact strength than the steels dealt with in Part I.—A. G.

Some Properties of Low-Alloy High-Tensile Steels Containing Molybdenum. J. Pow. (*Alloy Metals Review*, 1953, **8**, Sept., 2–7). The use of high yield strength steels and the influence of common alloying elements on tensile strength are outlined. It is pointed out that the most economical method of obtaining an increased yield stress in a high-manganese steel is by the addition of molybdenum. Some properties of manganese-molybdenum steels are described.—V. G.

Iron, Mild Steels, and Low-Alloy Steels. H. L. Shaw. (*Indust. Eng. Chem.*, 1953, **45**, Oct., 2205–2210). Information relating to uses for chemical engineering construction published in 1951–52 is reviewed. Restrictions on alloying elements were alleviated by boron steels. Coarse-grained Cr–Mo steels have been developed for high temperature and high pressure steam services. The joining of clad steels has been improved by inert-gas-shielded metal arc welding. Aluminium coatings for corrosion prevention have been developed. (85 references).—K. E. J.

Pearlite-Free Basic Bessemer Steel: Its Fabrication and Properties. A. Josefsson. (*J. Iron Steel Inst.*, 1954, **177**, May, 118–128). Steels containing less than 0·015% of carbon, here termed 'pearlite-free', are characterized by much lower impact transition temperatures than steels with similar base composition and slightly higher carbon contents. Provided that this carbon limit is not exceeded, phosphorus and nitrogen up to 0·15% and 0·020% respectively, may be used as alloying additions to give a yield strength comparable with that of plain carbon steel containing 0·15–0·20% C, without noticeable impairment of the impact properties even after straining and ageing. The manganese content should be kept rather low, about 0·20%; higher percentages are probably unfavourable to low-temperature ductility after slow cooling. Pearlite-free steels of this type are shown to be easily and economically produced by the basic Bessemer process. Examples of results from impact tests on plates of these steels are given, together with results of bend tests on welded specimens. Corresponding data for plain carbon steels are included for comparison.

Testing Pipes by the Method of Ring Specimens. M. P. Zheldak. (*Zavodskaya Laboratoriya*, 1950, **16**, (10), 1237–1241). [In Russian]. The following conclusions are drawn from a study of the mechanical properties of pipes made from different steels subjected to various heat-treatments: For soft steels in the annealed state, tensile strength values obtained with ring specimens and flat specimens agree. For high-strength pipes, ring specimens normally give high tensile strength values, but the divergence can be reduced by adjusting the test conditions. Ring specimens lead to greatly reduced values for relative elongation with both annealed and normalized steel. The reduction of area at the neck of ring specimens in the normalized state does not give a true indication of plasticity. The use of ring specimens in conjunction with conversion factors experimentally determined for each type of steel is recommended.—S. K.

Low-Carbon Bessemer Steel and Its Use for Welded Structures. A. I. Krasovskii, M. M. Kraichik, and N. N. In'shakov. (*Avtog. Delo*, 1953, (5), 1–6). [In Russian]. An experimental study of the mechanical properties at different temperatures and in various stages of deformation and heat-treatment of two Bessemer and one open-hearth steels is reported. The former, containing 0·02% nitrogen, have higher elastic limit, yield point, and ultimate strength, but inferior plastic properties and impact strength than the latter. Welds in Bessemer steels tended to show brittle fracture to such an extent that their use in important members subjected to variable stresses at low temperatures is not possible. Optimal welding conditions for Bessemer steels are listed.—S. K.

Stresses in the Steel-Clad Jackets of Cellulose Digesters. E. Kirschbaum. (*Werkstoffe u. Korrosion*, 1953, **4**, Aug.-Sept., 280–290). By inserting sets of thermocouples at several places the author studied the distribution of temperature across the inner stonework and the outer steel cladding of the jacket of a cellulose digester. Explosions sometimes result from the stresses set up by these temperature differences. He concludes that, if such accidents are to be avoided, the coefficient of expansion of the acid-resisting lining must not exceed $0{\cdot}92 \times 10^{-5}$ mm./° C. and gives a number of precautions to be observed during the operation of the plant.

New Structural Steels. T. Malkiewicz. (*Hutnik*, 1953, **20**, (10), 203–207). [In Polish]. New standards for structural steels are discussed. The old standards were revised in order to co-ordinate Polish standards with those of the U.S.S.R.

Effect of Grain Size and Carbon Content on the Low Temperature Tensile Properties of High Purity Fe–C Alloys. R. L. Smith, G. Spangler, and R. M. Brick. (*Amer. Soc. Met. Preprint No.* 3w, 1953). Several low-carbon ferrites, approximately 99·9% pure, apart from added carbon, and substantially free from oxygen, nitrogen, and hydrogen, were prepared and tested in tension under various conditions of heat-treatment, ferrite grain size, and test temperature. True stress/strain curves were calculated and the significant tensile parameters evaluated. Ferrite grain size was shown to be the sole factor determining ductility of 0·02% carbon alloys at liquid air temperature; decreasing the grain size caused a remarkable increase in ductility. With more than 0·02% carbon, carbide morphology had an important effect on the ductility. Heat-treatments which resulted in carbides at the grain boundaries materially reduced the low-temperature ductility. The exponent of strain hardening was found

to decrease with decreasing temperature, increasing carbon content, and increasing size.—J. C. B.

Rôles of Aluminium and Nitrogen in Graphitization. E. J. Dulis and G. V. Smith. (*Amer. Soc. Met. Preprint No.* 2w, 1953). From observations that addition of nitrogen inhibited graphitization of a high-purity iron-carbon alloys, that aluminium is not necessary for graphitization of high-purity iron-carbon alloys, and that the susceptibility to graphitization of steels of commercial purity containing nitrogen and aluminium decreased directly with increase in uncombined nitrogen, it is concluded that: (*a*) Nitrogen inhibits the breakdown of cementite to graphite; and (*b*) aluminium promotes graphitization through its rôle as a scavenger for nitrogen.

Stainless Steels and Other Ferrous Alloys. W. A. Luce. (*Indust. Eng. Chem.*, 1953, **45**, Oct., 2241–2254). Recent literature on chemical engineering construction is reviewed. Conservation of critical elements is emphasized, although molybdenum and niobium allocations have been increased. The substitution of manganese for nickel in austenitic stainless steels became a commercial process. Information is given on corrosion resistance, high temperature properties, physical and mechanical characteristics, and welding techniques for stainless steels. (303 references).—K. E. J.

18-8 Stainless Steels. (*Chem. Eng.*, 1953, **60**, May, 300–312). This summary, issued by the Committee of Stainless Steel Producers of Amer. Iron Steel Inst. describes the properties, characteristics, and uses of the basic 18% Cr, 8% Ni, 0·08–0·2% C stainless steel, and of modifications of this type. Data are given on the chemical composition, physical and mechanical properties, and working characteristics of these steels, and the effect on them of 129 substances is shown in concentration/corrosion-rate/temperature charts.—D. L. C. P.

Properties of Chemical Engineering Materials of Construction. (*Indust. Eng. Chem.*, 1953, **45**, Oct., 2270–2282). Tabulated data and references are presented on analyses; physical, mechanical, electrical, and thermal properties; and corrosion resistance; for aluminium alloys, carbon and graphite, cements, iron, mild steels, low-alloy steels, and nickel alloys.—K. E. J.

Precipitation Hardening Steels. G. A. Fairbairn. (*Machine Design*, 1953, **25**, Feb., 305–314). The heat-treatment (and associated distortion and ageing effects), mechanical properties, and corrosion resistance of three stainless irons suitable for aircraft applications, are described. These irons contained: (1) 16·5% Cr, 3·5% Ni, 3·5% Cu, 0·35% Nb + Ta; (2) 17% Cr, 7% Ni, 1% Al; and (3) 17% Cr, 7% Ni, 1% Al + Ti.

Carbon Steel Can Replace Alloy for Small Diameter Bolts. A. S. Jameson, J. A. Halgren, and R. H. Pinkel. (*Iron Age*, 1953, **172**, Sept. 17, 153–156). Hardenability is made use of in replacing a molybdenum alloy with a carbon steel for ⅜-in. bolts. Quenched and tempered bolts are quenched out to a centre hardness of Rockwell C 45, which represents a 50% martensitic structure, tempering at not less than 800° F. Tensile strength of 2 × ⅜-in. coarse-thread bolts reaches 150,000 lb./sq. in. when tested under a 10° wedge and loading over a three-thread gauge length.—A. M. F.

Influence of Heat-Treatment on the Properties of Drawn Steel Wire. H. Weil. (*Draht-Welt: Wire and Wire Products*, 1953, **28**, Aug., 788–790, 819–827). Structural changes in two steel wires with 0·48% and 0·74%-C respectively was investigated during patenting. The necessary austenitizing temperatures and isothermal transformation diagrams were determined. The effect of double patenting and patenting preceded by annealing was studied on 0·34%, 0·53%, and 0·69%-C steels. The structures were correlated with drawing behaviour and mechanical properties of the drawn wires, and conclusions are drawn concerning the rôles of ferrite and cementite in determining the rate of work hardening, and the performance in the torsion and bend test, the shape and distribution of the cementite grains being of particular importance.—J. G. W.

Proposed New Scales for Expressing the Stiffness of Round and Flattened Wire. J. M. Thomas and L. Thomassen. (*Wire and Wire Products*, 1953, **28**, Sept., 875–876, 924). An improvement on the A.S.T.M. method for testing the stiffness of round and flat wire for electric resistance heating appliances is proposed.—J. G. W.

Composition and Mechanical Properties of Steel Used in Bridge Building in the Period 1870–1880. E. H. Schulz and W. Bischof. (*Stahl u. Eisen*, 1953, **73**, Nov. 19, 1583–1590). The chemical composition, tensile strength, yield point, elongation, reduction of area, impact strength and resistance to ageing of samples of puddled and Bessemer steels from six old Dutch bridges are compared with those of modern steel used for the same purpose.—J. P.

Influence of the Principal Manufacturing Processes on the Quality of Titanium-Stabilized Austenitic Ni-Cr Steel Castings. Z. Eminger. (*Hutnické Listy*, 1953, **8**, (6), 282–297). [In Czech]. The theory of the stabilization of Ni-Cr steels by adding titanium is explained. Procedures during the melting are discussed, both in relation to the basic arc furnace and acid H.F. furnace processes are described. Carbon and titanium losses during melting and pouring are calculated, and methods are given for determining the type and quantity of scrap in the charges. Casting of Ni-Cr steels in sand moulds and the influence of heat-treatments and titanium content on the tensile strength, impact strength, and elongation are discussed.—P. F.

Heat-Treatment—An Important Factor in Relation to the Quality of Plain and Low-Alloy Structural Steels. F. Šícha. (*Hutnické Listy*, 1953, **8**, (10), 521–527). [In Czech]. The possibility of improving the mechanical properties of basic-Bessemer, Talbot, and Izett steels is discussed. The relation between nitrogen content and the contents of other elements in converter steels, the influence of the cooling rate from the normalizing temperature in rimming converter steels, before and after ageing on their hardness, tensile strength, impact strength, hardenability, and other properties are considered.

Carbon in Ferrous Alloys. H. K. Thrig and J. T. Jarman. (*Amer. Foundryman*, 1953, **24**, Nov., 52–57). The authors discuss the effect of carbon content on the mechanical and physical properties of steel and iron. Experimental results are presented to show the influence of carbon content on the strength and hardness of plain carbon and low-alloy steels, and the effect of microstructure on the properties of cast iron.—B. C. W.

Russian Steels Today. C A. Zapffe. (*Mat. Methods*, 1953, **38**, Aug., 79–86). A detailed picture is presented of the steels now being used in Russia. The author explains how the steels are classified by application, and gives compositions and applications of the commonly used grades. Four major classes cover all Russian steels : Structural ; Machine (general and special purpose) ; Instrumental ; and Special. Within these classes are 22 groups. The class number, group number, identifying letters, analysis, and applications are tabulated for some 250 steels.—P. M. C.

Ferrous Castings in the Refractories Industry. E. J. Brown. (*Refract. J.*, 1953, **7**, July, 289–293). In selecting metals to be used for crushing and grinding in the refractories industry consideration should be given to the characteristics of the material to be crushed and the type of steel or alloy most resistant to the conditions. Manganese steel and high-chromium iron are considered and the application of tungsten carbide coverings by electric welding is briefly described.

Influence of Various Elements on Mechanical Properties of Cast Iron Produced by Treatment with Slag Containing TiO_2. (S-H Cast Iron). (I). H. Sawamura, Y. Hotta, and T. Oka. (*Tetsu to Hagane*, 1953, **39**, May, 520–523). [In Japanese]. ' S–H ' cast iron has higher tensile and transverse strengths than grey iron when the carbon content is above 3·3%: below this figure they are lower. Hardnesses are generally higher than those of grey irons.—K. E. J.

American Standard Specification for a Mechanical Joint for Cast Iron Pressure Pipe and Fittings. (*J. Amer. Water Works Assoc.*, 1953, **45**, Apr., 431–442). This specification covers a bolted joint of the stuffing-box type in sizes from 3 to 48 in. for cast-iron made by sand-cast or centrifugal methods.—A. D. H.

Martensitic White Cast Iron Resistant to Wear by Abrasion. (*Fonderie*, 1953, May, 3444–3445). The structure, composition, and manufacture of martensitic white cast iron are briefly described. The alloy used had the approximate composition C 3·0%, Si 0·7%, Mn 1·0%, Ni 4·0–5·0% and Cr 1·0–2·0%, and, if correctly treated, it had a surface hardness of 700 Brinell.—B. C. W.

Impact Properties of Annealed Spheroidal-Graphite Cast Iron. A. L. Carr and W. Steven. (International Foundry Congress : *Metal Treat. and Drop Forg.*, 1953, **20**, Oct., 455–461). Details are given of experiments in which the notched and unnotched impact properties of fully and partially annealed magnesium-containing spheroidal graphite irons were determined at temperatures within the range −150° to +300° C. The results show well-defined impact transition

temperature ranges and that increasing the silicon, manganese or phosphorus, or increasing the proportion of pearlite in the matrix structure, raises transition temperature ranges and decreases impact values at temperatures above these ranges. (13 references).—P. M. C.

The Mechanism of Fracture in Cast Irons. Z. Kadeřávek. (*Hutnické Listy*, 1953, **8**, (4), 171–174). [In Czech]. A fractographic study was made of the fracture mechanism in cast irons. At the instant of impact an elastic wave is first propagated through the metallic matrix and the graphite flakes embedded in it, causing some of the flakes to split. In the subsequent stage of fracture, stress concentrations arise at the edges of the fractured graphite flakes which are sufficient to spread the cracks through the metal between the flakes.—P. F.

The Materials Testing Laboratories. J. P. Bohnenblust, A. Gandenzi, and H. Zschokke. (*Brown Boveri Rev.*, 1953, **40**, Aug., 305–320). The chemical, physical, mechanical, and metallographic sections of the Brown Boveri laboratories are described in detail and the scope of their work indicated. There are numerous photographs of the equipment.—L. D. H.

METALLOGRAPHY

The Phase Contrast Microscope and Interferometric Microscopy. F. Muñoz Del Corral and M. P. de Andres. (*Inst. Hierro Acero*, 1953, **6**, July-Sept., 237–248). [In Spanish]. The principle of the phase-contrast microscope and of interferometric microscopy, together with some examples of their application, are described. The limitations of these methods are discussed.—R. S.

Simple Equipment for Taking Debye-Scherrer Photographs at High Temperatures. K. Toman. (*Hutnické Listy*, 1953, **8**, (7), 350–351). [In Czech]. A small silica tube, electrically heated by an internally wound helix of platinum wire is the principal feature of a small furnace suitable for use in standard X-ray cameras for powder photographs at up to 700° C. The powder to be examined is spread on the furnace at the spot where the beam falls, lanolin serving as carrier. The powder adheres to the tube even after the decomposition of the lanolin at the high operating temperatures.—P. F.

Metals, Alloys, Fluxes and Slags. A. H. Cottrell. (*Trans. Faraday Soc.*, 1953, **49**, May, 515–521). The elucidation of the structure and mechanism of structural changes in metals and alloys by means of the optical reflection microscope and X-ray techniques is reviewed.—B. G. B.

Iron and Steel. (*J. d'Informations techniques des Industries de la Fonderie*, 1953, Feb.-Mar., 19–22 ; May, 19–21 ; June-July, 17–19 ; Sept., 17–19). Elementary considerations of the metallography of cast iron and steel are given in this series. Pure iron, ferrite, austenite, cementite, and graphite are briefly considered.—A. D. H.

How To Understand Plain Carbon Steel. S. Storchheim. (*Machinist*, 1953, **97**, Oct. 10, 1695–1702). The article explains the composition and crystal structure of iron and steel together with the effects of heat treatment, including carburizing, and nitriding.—M. A. K.

Inside Look at Hardening Cast Iron. J. Obrebski. (*Steel*, 1953, **133**, Dec. 28, 71–73). Factors influencing the structure and properties of cast-iron parts are considered. The influence of analysis and heat-treatment are explained with particular reference to hardness. The description is illustrated by 11 microphotographs. The example of lathe-bed castings is given particular attention.—D. L. C. P.

Metallography of Sintered Carbides in the Works Laboratory. D. Friedl. (*Hutnické Listy*, 1953, **8**, (5), 246–249). [In Czech]. Suitable methods of preparing metallographic specimens of sintered carbides are described. The structure of the phases in carbides is discussed and illustrated by micrographs.—P. F.

Fast Polishing Method Brings Out Graphite. R. W. Lindsay and J. M. Snook. (*Amer. Foundryman*, 1953, **24**, Nov., 48–50). A rapid metallographic polishing method for graphite structures is described. After polishing on belts and papers, the specimens are wet polished on a silk lap with a thick suspension of a coarse grade of chromic oxide. The final polish is on a similar lap with a finer grade of chromic oxide.—B. C. W.

The Effect of Cold Work on an Iron-Manganese Alloy. J. G. Parr. (*J. Inst. Metals*, 1953, **82**, Oct., 92, 91). Cold-working an iron–manganese alloy produces metastable phases in quantities which depend upon the extent of cold-working. This effect—and the different constitutions of filings made in air and under liquid—is demonstrated by phase analyses made on filings of different sizes.—B. G. B.

Nature and Properties of the Grain Boundaries of Polycrystalline Metallic Bodies—Review of New Work. K. Lücke. (*Z. Metallkunde*, 1953, **44**, Aug., 370–378 ; Sept., 418–426). A general survey is made of the present state of knowledge of grain boundary theory under the headings : Plasticity and inelasticity of the grain boundaries ; theory of grain boundary plasticity ; experimental study of grain boundary energy ; general grain boundary theory ; diffusion at grain boundaries ; and twinning and two phase boundaries. (71 references).

A Hypothesis for the Boron Hardenability Mechanism. J. W. Spretnak and R. Speiser. (*Amer. Soc. Metals, Preprint No.* 20, 1953). A working hypothesis for the mechanism of the boron hardenability effect is formulated from a critical appraisal of existing knowledge on boron metallurgy and of the fundamental mechanism of retarding the rate of decomposition of austenite in steels. The importance of the allotropic transformation in determining the kinetics of decomposition of austenite is discussed; the conditions leading to partitioning of alloying elements in the formation of pro-eutectoid ferrite and pearlite are evaluated. It is postulated that ferrite forms from austenite by a shear mechanism and that the boron effect is a solid solution effect giving rise to scattering points which act as impediments to the shearing process. The magnitude of the strain energy effects in austenite is calculated for carbon, nitrogen and boron.—J. R. P.

The Nature of Martensite. B. A. Apaev. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93**, (4), 647–649). [In Russian]. The homogeneous or heterogeneous nature of martensite is discussed. Magnetic investigation showed that the electrolytic residues obtained from a quenched steel specimen were not a ' martensitic carbide ' but a finely dispersed martensite powder, thus presenting additional proof of the homogeneity of martensite in quenched steels.—V. G.

Metallographic Investigation of Non-metallic Inclusions in Steel by a Novel Thin Section Technique. E. Folkhard. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 519–522). A procedure is described for examining the non-metallic inclusions in steel. The process can be applied only to silicon steel electrical sheet. A thin section of the steel is prepared (thickness 50% to 10% of the mean grain size) and the ferrite matrix dissolved in an alcoholic glycerine solution of bromine. The non-metallic inclusions and carbon from the decomposition of carbides remain and are disposed in their original positions in the matrix ; the transparent gelatinous silica resulting from the dissolution of the silicon acts as a supporting medium. By examining the residues with a binocular microscope it is possible to ascertain how they were related to the original structure of the metal. It has been shown in this way that grain boundaries are preferred sites for the precipitation of non-metallic inclusions. Such fine inclusions are not visible in an ordinary metallographic section.—J. P.

Electron Micrographs of Crystal Boundary and Sub-Boundary Structures in Steels and Ingot Irons. E. W. Williams and H. O'Neill. (*J. Iron Steel Inst.*, 1954, **177**, June, 224–228). [This issue].

A Crystallographic Analysis of the Ductile-Brittle Transition in Body-Centered Cubic Single Crystals. A. J. Opinsky. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197** ; *J. Met.*, 1953, **5**, Dec., 1650–1651). The author applies the laws of critical normal stress for cleavage and critical shear stress for slip to explain the orientation and temperature dependence of the ductile-brittle transition in body-centred cubic metals.

The influence of Rate of Heating on the Recrystallization of Steel. B. G. Sazonov. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93**, (5), 817–820). [In Russian]. Samples of steel (C 0·41%, Cr 1·41%, Ni 0·03%) quenched from 1300° C. in oil were heated in the temperature range 700–1200° C. at heating rates of 3° and 200° C./min. and quenched in water. The microstructure of samples fractured in liquid nitrogen was studied. It was found that at low and very high heating rates the austenite is regularly orientated, at intermediate heating rates austenite is mainly unorientated in relation to the initial state.—V. G.

Study on Heat-Treatment of the Ball Bearing Steel (I). T. Mitsuhashi and M. Ueno. (*Tetsu to Hagane*, 1953, **39**, July, 722–732). [In Japanese]. For SUJ2 steel, the best austenitizing temperature was 840±5° C. Oil quenching and tempering gave superior results to sub-zero heat-treatment in

the compressive breaking test, but notch brittleness was produced. Martempering produced acicular bainite, with low hardness but good mechanical properties. Lineal analysis was found best for determining retained austenite. (14 references).

Study on High Speed Tools. (XV). H. Hotta and I. Tatsukawa. (*Tetsu to Hagane*, 1953, **39,** June, 614–619). [In Japanese]. The effect of austempering on the subsequent tempering behaviour was studied in a high-speed steel containing tungsten, chromium, vanadium and cobalt. Isothermal transformation only occurred in the austempering range 250–350° C. Changes in hardness differed from those resulting from oil quenching. After austempering in the bainite tange, considerable secondary hardening was observed. (21 references).—K. E. J.

Tool Steels and Their Heat-Treatment. R. Štefec. (*Hutnické, Listy*, 1953, **8,** (9), 461–464). [In Czech]. The isothermal decomposition of austenite, the temperature of the martenitic transformation, deformation on quenching, retained austenite, heat-treatment at sub-zero temperatures, economy in alloying elements, and new types of tool steels are discussed. TTT-diagrams of a number of Poldi steels are given, together with data on the influence of quenching conditions on the amount of retained austenite.—P. F.

Sub-Zero Heat-Treatment of Tool Steels. O. Morávek. (*Hutnické Listy*, 1953, **8,** (9), 464–470). [In Czech]. Experiments to determine the effect of sub-zero heat-treatment of high-speed steels on the amount of residual austenite are reported. Details of the procedures are given, and their significance is explained by **S**-curves and micrographs. With many low-alloy steels, or with carbon steels, a single treatment at −78° C., carried out immediately after quenching, considerably reduced the retained austenite content. Steels must be tempered after freezing. Further experiments are in progress to facilitate decisions as to large-scale industrial applications of the method.—P. F.

Effect of Nonmartensite Decomposition Products on the Properties of Quenched and Tempered Steels. E. F. Bailey. (*Amer. Soc. Metals Preprint No.* 11, 1953). Times necessary for 10% and 30% decomposition to ferrite, pearlite, and bainite in a 0·40%-carbon steel, a 3·50%-Ni steel, and a chromium steel were determined using Charpy specimens quenched into isothermal baths. Test-bar blanks were given the determined treatments for isothermal decomposition of austenite and tempered to 150,000 lb./sq. in. tensile strength. Generally, no significant damage to mechanical properties as compared with the fully quenched and tempered condition resulted from 10% decomposition. The magnitude of the damage to the mechanical properties caused by 30% decomposition was not the same for the three steels, but, in general, the 700° F. bainite had no injurious effect and, as the temperature of decomposition increased, the greater was the deterioration in mechanical properties.—J. B. P.

Formation of Martensite in Austenitic Stainless Steels: Effects of Deformation, Temperature and Composition. T. Angel. (*J. Iron Steel Inst.*, 1954, **177,** May, 165–174). The isothermal formation of martensite induced by plastic deformation has been studied in austenitic stainless steels in the temperature range −188– +100° C. as a function of stress, strain, and deformation energy. The influence of temperature is discussed in terms of the relation between the martensitic and the slip mode of deformation. The main transition between the two modes was found to take place within a narrow temperature range. In this range a modified version of M_d was chosen, termed M_{d30} giving a measure of the austenite stability easier to determine practically. The effect of composition on the austenite stability in regard to martensite formation was evaluated statistically. It was found that that action of Cr, Si, and Mo was the same as that of Ni, Mn, C, and N_2, in that they all tend to stabilize the austenite. Finally, the anomalous increase in stress observed in the stress/strain curve was found to be proportional to the amount of martensite formed and also to the carbon content of the martensite.

The Mechanism of the Austenite–Martensite Transformation. H. Knapp. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 497–504). Some recent work on the crystallography of the austenite→martensite transformation is reported. The shift of atoms can be represented by a single matrix. The habit plane is not rotated by this deformation. The investigations of the surface effect show that the transformation does not occur as a single homogeneous deformation. The matrix of the total shift of atoms is to be divided into two components. One set of displacements is homogeneous, *i.e.*, it causes a macroscopic visible deformation. The other displacements are homogeneous in very small regions only, between which slip takes place. The transition from the austenite to the martensite lattice can be achieved by a system of screw dislocations. Considerations of energy requirements and structure indicate directly the possible shifts and the most favourable lattice orientation relationships and show, moreover, that the atoms can migrate to new lattice sites without requiring a thermal activation energy.—J. P.

The Use of Continuous-Cooling Transformation Diagrams in Problems of Heat-Treatment. A. Rose and W. Strassburg. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 505–514). The restricted value of isothermal as compared with continuous transformation diagrams is discussed. The course of cooling in work pieces of heavy cross-section is similar to that in dilatometer test pieces from which the transformation diagrams are derived, and the latter are therefore directly applicable to technical heat-treatment processes. A definite structure and hardness value can be related to only one cooling procedure among a group of similar procedures. It is thus possible to determine the course of cooling in the interior of heavy specimens with the aid of continuous transformation diagrams. For the numerical characterization of hardenability, it is recommended that the critical cooling times be determined for the zone of martensite formation, for the initiation of ferrite formation and for complete pearlite formation. These critical cooling times have been assembled for a number of case-hardening and heat-treatable steels and related to the cooling behaviour of cylindrical specimens during water, oil, and air quenching.—J. P.

Anisotropic Dimensional Changes When Heat-Treating Ledeburitic Chromium Tool Steels. J. Frehser. (*Arch. Eisenhüttenwesen*, 1953, **24,** Nov.-Dec., 483–495). The transverse and longitudinal thermal coefficients of linear expansion of ledeburitic and non-ledeburitic tool steels have been determined in the cast state, after deformation, and in the hardened and tempered conditions. The results enable qualitative predictions to be made as to the total dimensional changes of slab-shaped pieces. In some conditions, thermal expansion is anisotropic. It has been found that carbides decrease the thermal expansion coefficient. The coefficient of ledeburitic steels with carbides having a preferred orientation is smaller in the direction of the carbide lines than in directions at right angles thereto. It was proved that the greatest dimensional changes during heat-treatment take place in the direction of least thermal expansion. From this it can be concluded that the cause of anistropic dimensional changes is the restrictive action of the carbides on the matrix during the rapid cooling on hardening.—J. P.

Can I Benefit from the Use of Low Temperature Treatment? H. C .Boyer. (*Steel Processing*, 1953, **39,** Oct., 502–508). The elements of quench hardening and the $\gamma \rightarrow \alpha$ transformations in steels are described. Experiments were carried out by the author on five steels to determine the hardness and percentage of retained austenite after cooling to temperatures down to −150° F. following standard hardening practice. The results for steels with 1% C, 1% C + 1½% Cr, 2% C + 12% Cr + 0·8% Mo, 1% C + 17% Cr + 0·4% Mo, and 0·7% C + 4% Cr + 18% W + 1% V, all show progressive increase in hardness and decrease in the amount of retained austenite. The effect of subsequent tempering and the uses and applications of low temperature treatment are reviewed.—P. M. C.

The Determination of Bond Energy in the Austenite Lattice. Yu. V. Kornev. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93,** (3), 467–470). [In Russian]. By measuring the amount of iron condensing from a stream of atoms passing through a small thin-walled aperture, the heats of sublimation (E) of pure γ-iron and iron in austenite containing 5·8 at.-% of carbon were determined as 103·5 ± 0·6 kg. cal./g. at. and 43·5 ± 0·3 k. cal./g. at. respectively. The heats of self-diffusion (Q) for pure γ iron and for austenite (5·8 at.-% of carbon) were calculated as 69 amd 28·5 k. cal./g. at. respectively. The ratio Q/E was 0·67 for pure iron and 0·66 for austenite, which corresponds to that of pure non-ferrous metals with the co-ordination number 12 (Q/E approx. 0·66). Thus

Q/E is constant not only for pure metals but also for solid solutions. It is therefore assumed that the energy of activation of self-diffusion can be used as a measure of the bond strength of crystal lattices of both pure metals and solid solutions. From the data obtained it is concluded that the addition of 5·8 at.-% of carbon, diminishes the bond energy of the γ-iron lattice from 103·5 to 43·5 kg. cal./g. at. The apparatus and experimental technique are described.—V. G.

Diffusion and Solubility of Boron in Iron and Steel. P. E. Busby, M. E. Warga, and C. Wells. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**; *J. Met.*, 1953, **5**, Nov., 1463–1468). From de-boronizing experiments, the authors have derived fundamental data on the rate of diffusion of boron in austenite and on its solubility in α-iron and γ-iron, thus providing partial explanations for some of the phenomena observed in boron steels. A tentative Fe–B phase diagram at low boron concentrations is put forward, and an equation representing diffusion of boron in austenite is presented.—G. F.

The Influence of Carbon on the Self-Diffusion of Iron in the Iron–Nickel System. P. L. Gruzin and E. V. Kuznetsov. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **93**, (5), 809–812). [In Russian]. The influence of carbon on the self-diffusion of iron in Fe–Ni alloys was studied, using radioactive Fe_{59}, in the temperature ranges 800–1300° C. and 1050–1330° C. for alloys containing 20% and 25% of nickel respectively. The time of diffusion heating was such that the diffusion layer was 40–50 times thicker than the electroplated layer of radioactive iron. The dependence of the coefficients of self-diffusion of iron on the carbon content of the iron–nickel alloys are represented by the formulæ: (1) for alloys containing 20% of nickel

$$D_{\text{Fe-Ni-C}} = 18 \cdot 10^{-0 \cdot 92p} e^{-\frac{75000-6000p}{RT}};$$

and (2) for alloys containing 25% of nickel

$$D_{\text{Fe-Ni-C}} = 71 \cdot 10^{-0 \cdot 65p} e^{-\frac{79000-5009p}{RT}};$$

where p is the carbon content in at.-%, R a gas constant, and T the temperature (° K.) It is concluded that carbon lowers the bond energy of atoms in solid solutions of iron and nickel.

The Exchange Reactions in the Iron–Silicon System. E. Fitzer. (*Z. Metallkunde*, 1953, **44**, Oct., 462–472). After giving an introductory survey of diffusion processes in multiphase systems, the author discusses the experimental results of investigations of the exchange processes in the iron–silicon system, and shows that the diffusion coefficients are closely related to the concentration. The unsymmetrical diffusion causes a displacement of iron into the silicon, resulting in porosity and a breakdown of the iron in contact with the silicon, associated with an increase of volume in the latter. The practical implications of the observed results are discussed.

CORROSION

Corrosion Problems. B. Waeser. (*Werkstoffe u. Korrosion*, 1953, **4**, Dec., 437–442). This is a general review of recent developments with 86 references.—J. C. H.

Inhibitors and the Corrosion of Metals by Acids. I. L. Cavallaro, A. Indelli, and G. Bolognesi. (*Gazz. Chim. Ital.*, 1953, **83**, July-Aug., 540–554). After a brief reference to recent research in the field of inhibitors and the corrosion of metals by acids, the authors put forward a theory explaining the mechanism of this action. Research substantiating this theory is described. (27 references).—M. D. J. B.

Inhibitors and the Corrosion of Metals by Acids. II—Action of Certain Inhibitors on Polarographic Maxima. A. Indelli and G. Paucaldi. (*Gazz. Chim. Ital.*, 1953, **83**, July-Aug., 555–562). A relation between inhibitors and adsorption is established by measuring the drop in the maxima of polarographs. The authors also establish that the adsorption responsible for the inhibiting action is not related to the charge. (19 references).—M. D. J. B.

Inhibitions and the Corrosion of Metals by Acids. III—Action of Certain Inhibitors in Various States of Oxidation. A. Indelli. (*Gazz. Chim. Ital.*, 1953, **83**, July-Aug., 563–572). The author examines the effects of certain inhibitors on iron samples submitted to conditions of continuous immersion, alternate immersion, and exposure to air. He shows that the very marked effect of certain inhibitors is noticeably diminished when the surface of the metal is appreciably oxidized by exposure to air. This confirms the theory that the principal action of inhibitors is to raise the hydrogen potential. (15 references).—M. D. J. B.

Inhibitors and the Corrosion of Metals by Acids. IV—Action of Certain Inhibitors on the Attack on the Fe-Fe_3O_3 System by HCl. L. Cavallaro and L. Felloni. (*Gazz. Chim. Ital.*, 1953, **83**, July-Aug., 573–578). The authors show that the action of certain inhibitors on the speed of corrosion of iron in HCl is strictly related to the presence of iron oxide (Fe_2O_3). Moreover, the oxide reduces the effect of the inhibitor; this is attributed to a cathodic reaction.—M. D. J. B.

Inhibitors and the Corrosion of Metals by Acids. V—Action of Certain Inhibitors on Metals of Low Potential. G. Bolognesi. (*Gazz. Chim. Ital.*, 1953, **83**, July-Aug., 583–595). The effects of certain organic substances on the corrosion of iron and cobalt by acids are studied, particularly the effects of thio-ureas, isothiocyanates, and aromatic amines which it is shown markedly slow down the speed of corrosion. These substances have, in addition, the characteristics of raising potential. (17 references).—M. D. J. B.

Electrochemistry and Corrosion. J. N. Agar. (*Trans. Faraday Soc.*, 1953, **49**, May, 533–539). A short discussion of the important advances made in the study of electrochemistry and corrosion during the first fifty years of the existence of the Faraday Society (1903–1953) is presented.

Effect of Hydrochloric Acid on the Corrosive Nature of Combustion Gases Containing Sulphur Trioxide. R. W. Kear. (*Fuel*, 1954, **33**, Jan., 119–120). The results of a preliminary study into this problem show that the effect of HCl is to increase the corrosive nature of gases containing SO_3. Its attack on steel surfaces, by flue gases from the combustion of coals with a high chlorine content, cannot be disregarded.

Corrosion Aspects of the Vanadium Problem in Gas Turbines. S. H. Frederick and T. F. Eden. (*Inst. Mech. Eng., Preprint*, Dec. 31, 1953). The effect of V_2O_5 and mixtures of V_2O_5 and Na_2SO_4 (present in certain fuel ash) on turbine fouling and corrosion is discussed in detail. No commercial alloy is immune from attack above 650° C., although nickel-base heat-resisting alloys (Nimonic type) offer higher resistance that austenitic steels. Corrosion can be considerably reduced by additives introduced with the fuel or by separate injection into the combustion chambers. Laboratory tests with additives such as ZnO, Al_2O_3 and Kieselguhr are reported, and rig tests have confirmed the beneficial effects of additives.—P. M. C.

Protective Ceramic Coatings *versus* the Corrosive Effects of Exhaust Gas. M. Lorant. (*Refract. J.*, 1953, **29**, Oct., 418–420). An account is given of an investigation into the corrosive effects of lead bromide vapours at high temperatures, as in aircraft exhausts. Several heat-resistant alloys were tested with and without protective ceramic coatings. A description of the tests (carried out at 1350, 1500 and 1650° F.) is followed by a résumé of the results. The alloys, attacked to varying degrees when exposed, were effectively protected by certain ceramic coatings.—D. L. C. P.

Adsorption, Cationic Exchange and Metallic Corrosion. I.—Cationic Exchange between Metals and Electrolytes. A. M. Baptista. (*Anal. Phys. Quim.*, 1953, **49B**, July-Aug., 479–493). [In Spanish]. The rapid changes of potential that occur when a metal is immersed in a solution containing the salts of another metal, even if the former is more noble, is explained as a cationic exchange between the metal and the electrolyte.

Adsorption, Cationic Exchange and Metallic Corrosion. II—Interpretation of the Experimental Results. J. Palacios. (*Anal. Phys. Quim.*, 1953, **49B**, July-Aug., 493–500). [In Spanish]. The results of experiments conducted at Lisbon, especially those made with radioactive isotopes show that all cations in the electrolyte contribute to the solution potential. An explanation is given of the cationic exchange between metals and liquids of some corrosion processes in the light of the experiments described and based on the adsorption theory.—F. R. H.

Corrosion Test on Welded Austenitic Chromium Nickel Corrosion-Resisting Steels. (*Rev. Sondure*, 1953, **9**, (3), 138–139). This article describes a new corrosion test for welds proposed by The International Institute of Welding. The scope of the test is to determine the sensitivity to intercrystalline corrosion after welding of stainless steels.

The Cathodic Protection Process and Its Application to the Protection of Underground Pipelines. H. Steinrath. (*Metalloberfläche*, 1952, **6**, Apr., A49–A52). Methods of protecting

buried tubes against corrosion by the use of an electric current are described. The two main processes—the generation of current with an auxiliary metal, and the application of an external current—are outlined, and examples are given.

Development and Metallographic Applications of Corrosion Micrographs of 18/8 Stainless Steel. M. Serra Ribera and S. Feliu Matas. (*Inst. Hierro Acero*, 1953, **6**, July-Sept., 249–258). [In Spanish]. A method is given for developing micrographs of the corrosion of 18/8 stainless steel. Two practical procedures are described, one derived from a cube and the other from an octahedral sample. Both types of corrosion micrographs refer to the plant section of the microcrystals. Three practical examples are given of the relationship between these micrographs and certain metallic properties such as rate of corrosion, orientation of the slip planes, and the edge planes.—F. R. H.

The Corrosive Properties of Soluble Cutting Oils. (*Metallurgia*, 1953, **48**, Nov., 233-240). The results of a series of tests on eleven soluble cutting oils to measure their corrosive effect on machine-tool cast irons, are considered. The work has been undertaken by the Production Engineering Research Assoc. Steel chips were placed on three types of cast iron plate and covered with the cutting oil to be tested, and the surface roughness of the corroded area was measured on a 'Talysurf' surface meter.—B. G. B.

Service Experience on the Effect of Corrosion on Steel-Cored Aluminium Overhead-Line Conductors. J. S. Forrest and J. M. Ward. (*Inst. Electrical Engineers, Advance Copy* S1611, 1953).

The Anodic Behaviour of Nickel in Solutions of Hydrochloric Acid, Sodium Chloride, and Nickel Chloride. W. Machu and A. Ragheb. (*Werkstoffe u. Korrosion*, 1953, **4**, Dec., 429–436).

Contribution to the Accelerated Testing of the Resistance to Corrosion of Electrolytic Chromium–Nickel Deposits. H. Hefele. (*Metalloberfläche*, 1952, **6**, Feb., B17–B24). The phenomena associated with the atmospheric corrosion of Cr–Ni and Cr–Ni–Cu deposits are described, and accelerated methods of testing are outlined, and the results compared with weathering tests. A table of tests, with references to the appropriate literature, is given.—L. D. H.

ANALYSIS

Contributions to Steelworks Chemistry. P. Klinger. (*Stahl u. Eisen*, 1953, **73**, Dec. 3, 1665–1668; Dec. 17, 1737–1739). The literature on analytical laboratory apparatus and methods of making qualitative and quantitative analysis of iron and steel is reviewed. (36 references).—R. A. R.

Gas in Ferrous Metals. (*Mémoires du Centre National de Recherches Metallurgiques*, (3), Oct., 1953). In a 147-page publication, experiments on the determination of oxygen, nitrogen, and hydrogen in iron and steel are recorded. The first three parts are devoted to the determination of these gases, AlN, and other nitrides. The behaviour of AlN and Fe_2N towards various reagents is described. The determination of total oxygen by reduction of oxides by cementation in aluminium powder is shown to give fair agreement with the vacuum-fusion method which is also reviewed. A method is given for the determination of residual aluminium involving attack by bromine-methyl-acetate solution followed by fusion of the residue and absorptiometric determination of aluminium. If the AlN content is known, the residual aluminium is obtained. The determination of non-metallic inclusions by the alcoholic iodine and electrolytic methods is described and discussed. Hydrogen determinations carried out by vacuum-extraction methods confirm the results of British workers. The 'chilled pencil' test for hydrogen determinations in liquid steel is briefly dealt with. Short notes deal with the factors affecting the hydrogen content of welds and its effect on the strength of steel. The application of the foregoing methods to steelworks' problems is described in the final part. The main results are: (*a*) During the basic-Bessemer process, the nitrogen content is lowest during decarburization; (*b*) the concentration of FeO and MnO are lowest during decarburization in the basic open-hearth; (*c*) ferro-alloys are shown to be a source of nitrogen and hydrogen; and (*d*) good mixing of slag and metal improves deoxidation in the basic electric process.—A. D. H.

Contributions on the Analysis of the Constituents in Pig and Cast Iron. W. Koch and J. Bruch. (*Arch. Eisenhüttenwesen*, 1953, **24**, Nov.-Dec., 457–464). By maintaining certain electrochemical conditions, a series of constituents, such as graphite, carbides, and phosphides, can be isolated from pig and cast iron. The composition of the ferrite can be determined from that of the resulting electrolyte. The isolated residues can be separated into graphite and carbide fractions by the use of liquids of appropriate density. This separation is practically quantitative if the residues are previously subjected to ultrasonic treatment. The fractions have been examined by microanalysis, X-ray diffraction, magnetic analysis, and with the optical and the electron microscopes. This investigation has shown that the electrolytic isolation process can be employed successfully for the examination of pig and cast iron. It was observed in these tests that the distribution of manganese between ferrite and carbides in most of the irons examined corresponded to that found in slowly cooled steels. The distribution in mottled hematite pig iron deviated markedly from the normal. The phosphorus contents of the ferrite were comparatively small and high proportions always occurred in the carbide fraction. In nodular graphite cast iron there is no enrichment of magnesium in the graphite fraction.—J. P.

Modern Spectrography—Speed Pays High Cost of Knowing. N. Lynn. (*Steel*, 1953, **133**, Nov. 30, 106–108). The article describes how the rapid, direct reading quantometer spectrograph is used to advantage in analysing high and low alloy steels, slags, and ores. By taking advantage of speed and ease of obtaining results the costly equipment may be an economic proposition.—D. L. C. P.

Determination of Silicon in Steel. M. Dvořák. (*Hutnické Listy*, 1953, **8**, (7), 355–356). [In Czech]. Developments in electrode design, and the use of an auxiliary counter-electrode in spectrographic analyses of steel are described, with special reference to the determination of silicon. The improvements described considerably shorten the time required for spectrographic analyses.—P. F.

Determination of Silica in Blast-Furnace Slags. Methods of Analysis Committee. (*J. Iron Steel Inst.*, 1954, **177**, June, 243–245). [This issue].

Mass Spectrometric Analysis of Solids with the High-Frequency Spark. J. A. Hipple and J. G. Gorman. (*Amer. Soc. Test. Mat. Spec. Tech. Pub. No.* 149, 1953, 10–16). Earlier work with the H.F. vacuum spark in mass spectroscopy is reviewed briefly. A suitably designed system of monitoring the ion current produced by this type of source permits the application of the techniques of electrical detection in place of the method of direct photographic detection previously required for such an erratic source. The analytical method for solid samples is described and results obtained for the analysis of six stainless steels are given.—B. G. B.

The Mass Spectrometer as a Tool for the Determination of Trace Element Impurities in Solid Samples. M. G. Inghram. (*Amer. Soc. Test. Mat. Spec. Tech. Pub. No.* 194, 1953, 1–9). Two mass spectroscopic methods of solid chemical analysis are discussed. The first is the Dempster vacuum spark method, which is analagous to the optical spectroscopic method in that its determines all elements present in a sample in one experiment. The second is the isotopic dilution method which determines only one element per experiment but has a very high sensitivity. The latter method is described in more detail.—B. G. B.

Influence of Oxide Layer and Distance Between Electrodes on the Accuracy of Quantitative Spectroscopic Analysis. J. Baláš. (*Hutnické Listy*, 1953, **8**, (7), 352–355). [In Czech]. Results are given of an experimental investigation of the influence of electrode surface cleanliness and electrode oxidation on the intensity of atomic and ionic spectral lines.—P. F.

A Direct Reading Precision Polarograph. H. A. Dell and C. H. R. Gentry. (*Philips Tech. Rev.*, 1953, **14**, Mar., 257–262). A polarograph is described which is direct reading, so that in making a quantitative analysis it is not necessary to plot a complete polarogram. The concentration of certain metal ions in the solution to be analysed can be deduced from the difference of two readings on the instrument. As cathode, use is made of a mercury drop which is renewed every 1 to 4 sec. The current flowing in the solution is measured at the moments just before the detachment of the drops. As an indicating instrument a cathode-ray oscilloscope is used. A circuit in which the graphical construction on the polarogram is simulated electrically enables the values of the current steps to be read directly on the instrument.—P. M. C.

Polarographic Determination of Iron. M. Spálenka. (*Hutnické Listy*, 1953, **8,** (7), 362–363). [In Czech]. A description is given of a reliable method of determining iron polarographically by the use of the iron complex formed with triethanolamine. The advantages of the method are discussed, and four applications for the analysis of alloys are described.—P. F.

Polarographic Determination of Aluminium in Steel. K. Nežerka and J. Pietrosz. (*Hutnické Listy*, 1953, **8,** (8), 418–420). [In Czech]. Details are given of the polarographic method of determining aluminium in steel by means of the direct polarographic wave and by means of the derivative of that wave form. The latter can be recorded if a suitable adapter is employed with the usual polarographic equipment. This method is shown to be rapid and reliable, about 6 hr. being required for aluminium determinations on 20 samples of unalloyed steels. The method is also applicable for the indirect determination of oxygen in steel by Horty's method, in which alumina, obtained from the steel after its solution in HCl, is estimated polarographically.—P. F.

A Gravimetric Method of Gas Analysis. J. Morsing. (*J. Iron Steel Inst.*, 1954, **177,** May, 175–182). A gravimetric method for the simultaneous determination of hydrogen sulphide, carbon dioxide, oxygen, unsaturated hydrocarbons, hydrogen, carbon monoxide, methane, ethane, and nitrogen (by difference) in fuel gases is outlined. The apparatus used is described, and details for carrying out the analysis are given. Two or three analyses may be made per day with one apparatus. The method is especially fitted for analysing producer gas, but with the appropriate absorbents other gaseous mixtures may be similarly analysed.

Application of Variance Analysis to Chemical Analysis of Steel Composition. M. Kamimori. (*Tetsu to Hagane*, 1953, **39,** June, 632–634). [In Japanese]. Statistical investigations of various methods of determining sulphur in special steels showed that specimen shape and combustion temperature had significant effects on the analyses.—K. E. J.

A Combustion Method for the Determination of Sulphur in Slag. Methods of Analysis Committee. (*J. Iron Steel Inst.*, 1954, 177, June, 233–238). [This issue].

An Investigation of the Combustion Method of Sulphur Determination in Ferro-Alloys and Complex Steels. Methods of Analysis Committee. (*J. Iron Steel Inst.*, 1954, 177, June. 239–242). [This issue].

HISTORICAL

From the Early History of Wire Production. F. M. Feldhaus. (*Draht, Engl., Ed.*, 1953, Dec., 48–49). Information on wire drawing in the XVIth and XVIIth centuries is extracted from court proceedings of the Nuremberg Rügamt.

A Great French Metallurgist: Henri Caron. (*Aciers Fins Spec. Franç.*, 1953, Nov., 101–103). [In English]. A brief biography of Henri Caron (1823–1876) and his metallurgical activities is outlined.—V. G.

ECONOMICS AND STATISTICS

Steel in 1953. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1953, **28,** Dec., 5–9). Statistics of the British iron and steel production, consumption, and exports in 1953 as well as prospects for the increase in the iron and steel output in 1954 are given.—V. G.

Steel Developments in Poland. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1953, **28,** Oct., 5–22). Present and planned capacity and output of the Polish iron and steel industry, the supply of raw materials, construction of new plants and the role of Russian ore supplies for achieving the production target are reviewed.—V. G.

Latin-American Steel. (*Metallurgia*, 1953, **48,** Oct., 159–164). Particulars are given of the ore, coal, electricity, and steel positions of Argentina, Brazil, Chile, Columbia, Mexico, Peru, and Venezuela.—B. G. B.

Iron and Steel Industry in China: Progress in Heavy Engineering. (*Iron Coal Trades Rev.*, 1953, **167,** Dec. 11, 1359–1363). A description is given of some of the Chinese machine tools exhibited at the Leipzig Fair in 1953, and personal impression of the present conditions in the Chinese coal, steel, and heavy engineering industries are outlined.—G. F.

MISCELLANEOUS

Presidental Address: Social Consequences of Iron and Steel. R. G. Lyttelton. (*J. Iron Steel Inst.*, 1954, **177,** June, 201–208). [This issue].

British Iron and Steel Research Association: Sketty Hall, Swansea. (*J. Iron Steel Inst.*, 1954, **177,** June, 229–233). [This issue].

The Universal Decimal Classification Applied to Metallurgical Literature. E. Öhman and J. P. Saville. (*J. Iron Steel Inst.*, 1954, **177,** May, 183–188). The authors explain the need for a rapid and accurate means of classifying metallurgical literature and, after discussing other systems, describe the Universal Decimal Classification, its construction and present state, and the means by which it is revised and kept up to date. The contributions made by The Iron and Steel Institute and Jernkontoret in revising the metallurgical sections are explained. The article concludes with a description of a method for making the system better known and more useful to metallurgical workers, by producing " Selected Schedules from the U.D.C. " for their special guidance.

Control of Metallurgical Standards. W. J. Harris, jun. (Amer. Standards Assoc.: *Indust. Heating.*, 1953, **20,** Aug., 1500–1510). Three examples are given to illustrate the need to translate government research findings into the standards and specifications necessary for better production of new products and equipment. Titanium, high-temperature alloys, and the fracture of welded structures are the examples discussed.—B. G. B.

How to Introduce a System of Preventive Plant Maintenance. L. Walter. (*Australian Machinery*, 1953, **6,** Oct., 12, 13, 15). The purpose of preventive maintenance, desired results, and a card index system designed to ensure correct and regular attention to maintenance details are discussed.—P. M. C.

The Smokescope. J. P. Strange. (*Steam Eng.*, 1953, **22,** Sept., 444–446). The methods of estimating smoke density in chimney gases are briefly discussed and a description is given of a new instrument for this purpose made by the Mine Safety Appliances Co., Pittsburgh, Pa. The image of a density disc is projected to a focal distance equal to that of the chimney and appears on a mirror surrounding the aperture through which the smoke is observed. This facilitates easy comparison and as the reference disc is viewed against the background adjacent to the chimney the estimation is unaffected by changes in illumination.—B. C. W.

Social Services and Social Welfare Work in The Iron and Steel Industry. (*Aciérs Fins Spec. Franç.*, 1953, Nov., 10–14). [In English]. Social services required by law, and voluntary services provided by the French iron and steel industry, are outlined. —V. G.

Analysis Method Helps Managements Solve Personnel Problems. W. B. Olson. (*Iron Age*, 1953, **172,** Oct. 15, 114–117). An outline is given of a method known as activity vector analysis for evaluating the capacity and potential of personnel.—A. M. F.

Training for Management. Sir Charles Renold and R. S. Edwards. (*Advancement Sci.*, 1953, **10,** (39), 299–311). The problem of the introduction of the university graduate into industry and his initial training for managerial responsibility is discussed.—V. G.

The Plant Engineer in Industry. A. J. MacIntyre. (*Trans. Inst. Eng. Ship. Scotland*, 1952–53, **96,** 13–33). The duties of plant engineers are discussed and the need for proper records and planning is emphasized. Works safety measures are also considered.—V. G.

BOOK NOTICES

" *Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand*, 1953." Publications, Vol. VII. " Handbook—Australia and New Zealand." 8vo, pp. 255. Illustrated. Melbourne, 1953 : Office of the Congress and Australasian Institute of Mining and Metallurgy. (Price 50*s.* Australian).

This volume is, naturally, more general and less specialized than the first six volumes of publications of the Congress (*see J. Iron Steel Inst.*, 1954, **176,** Mar., 335), but in its own way it is most comprehensive and useful. It has, of course, a bias towards the geology and the metallurgical industries of the Australian states and of New Zealand, so that, for

example, the section on education deals explicitly with technical education, and the geographical descriptions of the States do not enlarge upon their natural beauties, but there is much other information to be found. It ranges from the historical origins of the settlements to the distribution of electric power and the system of internal air services —a most surprising folding map indicates that, besides international airways such as B.O.A.C., Air France and Pan American, some twenty Australian companies operate, some flying clear across the continent, others tracing zig-zag paths from town to town. In all, from the industrial and social points of view, this volume is invaluable in the study of these two important members of the Commonwealth ; it may also be pointed out that lists of books for further study are also given, and that these include fiction, poetry and " belles lettres " as well as history, economics, and technology.—J. P. S.

HALL, E. O. " *Twinning and Diffusionless Transformations in Metals.*" 8vo, pp. (ix +) 181. Illustrated. London, 1954 : Butterworth Scientific Publications. (Price 30*s.*)

Although much information has been published on the subject of deformation, twinning and similar phenomena, the author of this treatise has endeavoured not only to collect scattered data on the relevant properties of metals into a single book of reference, but also to unify the underlying theories and to include an introduction to crystallography which will provide the student as well as the research worker with the necessary background. These objectives appear to have been admirably achieved.

The opening chapters, dealing with the structure and deformation of metal crystals, indicate the nomenclature employed in their designation and the use of stereographic projection in their representation ; they describe methods for the preparation of single crystals and explain the mechanism of deformation. Twinning is then considered, first from the crystallographic and then from the practical stand-point, the effects of stress and heat-treatment being reviewed in separate chapters. The section on heat-treatment is the only part of the monograph which might well have been re-arranged, since this very short chapter, which deals with theory as well as practice, could easily have been divided between the preceding and following sections. The latter presents clearly and in some detail the theories of twin formation based on dislocation and nucleation.

Finally, changes of crystal structure in metals and alloys are discussed, specifically those, like the martensite transformation, which arise without appreciable diffusion of the constituents. Useful appendices on crystallographic structure and formulæ are included, while not the least valuable part of the text is the bibliography accompanying each chapter.

Throughout the book considerable care has been taken with the mathematical treatment of slip, deformation, and twinning mechanisms, and illustrations which are largely self-explanatory have been chosen. The absence of an index for the latter does not in any way reduce their value. Critical reference to the work of other authors is justified by careful cross-relation of formulæ ; although at times the exact implication of the criticism is not fully explained, but, in general, cautious and well-authenticated inferences, drawn from the assembled data, are summarized at the end of each chapter and enhance the value of the exposition. While an attempt has evidently been made to keep the book as short as was compatible with such a comprehensive survey, there remains a feeling that specific examples of certain more common changes in crystal structure might usefully have been expanded and some account of the relationship between transformation and metallic creep could have been included.

This volume should be on the bookshelf not only of the student of metal physics and also of everyone who wishes to have at hand a book of reference summarizing available knowledge in this restricted field.—J. O. LAY

HALLIMOND, A. F. " *Manual of the Polarizing Microscope.*" 2nd edition. 8vo, pp. 204. Illustrated. York, 1953 : Cooke, Troughton & Simms, Ltd. (Price 15*s.*)

The study of polished and etched metal surfaces with the optical microscope has produced a body of experience which enables the metallographer to interpet the characteristic shapes or formations observed on a particular metal as indicative of the presence of certain phases. This valuable technique of " spotting " a constituent while at the same time observing its distribution and orientation is necessarily limited to metallic systems for which considerable experience has been built up. In cases where the addition of a new constituent has caused familiar phases to assume unfamiliar shapes and introduced new ones, the rapid microscopic examination has to be supported by more powerful X-ray techniques of identification. The possibility of developing methods, akin to those used in petrology, whereby use is made of the further optical characteristics of metallic reflection observable in polarized light, to identify more closely a metallic phase, has frequently been considered. Progress in this direction was, however, limited ; the somewhat specialized form of the traditional polarizing microscope forming an obstacle to a wide interest.

The appearance, in 1948, of Dr. Hallimond's " Manual of the Polarizing Microscope," which described the changes in the modern instrument consequent upon the use of polarizing films, was an important factor in renewing interest in the metallurgical applications of polarized light. The enlarged second edition of the manual, which now makes a welcome appearance, opens with a detailed account of the construction and correct adjustment of the polarizing microscope. Keeping to a description of the experimental effects to be observed and omitting formal mathematical treatment, the general methods of determining path difference and extinction conditions are fully described. The use of polarized light in the determination of metals and minerals is then elaborated and the particular methods required for the measurement of path difference and rotation in reflected light are conveniently collected in a following chapter. The generous use of excellent diagrams assists in making this portion of the book of particular use to the practising metallurgist who wishes to employ the techniques of polarized light. The final chapters describe the use of recently improved forms of visual microphotometer attachment and universal stages. This well-produced manual will contribute greatly to the improvement of generally known polarized light technique, a development which may be most rewarding for metallurgy.—J. HOLDEN

HENDERSON, J. G., and J. M. BATES. " *Metallurgical Dictionary.*" 8vo, pp. xi + 396. New York, 1953 : Reinhold Publishing Corporation. (Price 68*s.*)

Of those concerned with metals, the true metallurgist scarcely expects to use a metallurgical dictionary, but he is considerably outnumbered by all sorts of people, such as physicists, chemists, engineers, and even those on the sales side, who must know some metallurgy without it being their main subject. For such people a dictionary is often the most convenient form of presentation, and undoubtedly the one under review will be of considerable value. It contains over 5000 terms covering a wide range from process to physical metallurgy and embracing numerous related subjects.

The definitions in general appear to be satisfactorily made and to sufficient extent, with appropriate cross-references. The pages are attractively arranged and the volume is well produced. There is just one small criticism of the page arrangement : to the reviewer, who is not bound to any publishing conventions, the arrangement of the page numbers in the centre of the opened pages appears to slow down the speed at which cross-references can be followed up.

In addition to the main dictionary matter the book contains, in the form of appendixes, a useful list of abbreviations, and a general discussion on the metallurgy of steels and of a number of common non-ferrous metals, which extends over 27 pages.

The authors have achieved their aim of producing a dictionary which will be of much use to the many who have to deal with metals and metallurgy without themselves being of the select—and there are bound to be some terms of which even a metallurgist will be pleased to find an explanation.—A. R. BAILEY

LOW, BEVIS BRUNEL. " *Theory of Machines.*" (New and enlarged edition of an earlier publication entitled " Engineering Mechanics ".) 8vo, pp. vii + 472. Illustrated. London, New York, Toronto, 1954: Longmans, Green and Co. (Price 25*s.*)

This is a new and enlarged edition of "Engineering Mechanics" which was first published in 1942. It contains the greater part of this earlier work together with eight additional chapters. The book is well produced with a very adequate index, the text being well illustrated. There are exercises at the end of each chapter and worked examples are liberally supplied throughout.

The standard reached is that suitable for students preparing for the examinations of the Engineering Institutions or for those reading for an honours or pass degree. The author has included several matters which are not in the usual text-books, as for example, the analytical treatment of brakes, and in particular, the theory given for brakes with external contracting pivoted shoes. It is also refreshing to see a chapter on dimensional analysis and dynamical similarity, it is not usual to find much space devoted to these useful subjects.

Special attention has been paid to the inertia effect of connecting rods in the chapter on Turning Moments and Flywheels and to the creep of belts in the chapter on Rope and Belt Drives. Included in the chapters on gearing is a little known semi-graphical treatment, as well as the more usual tabular one, of epicyclic gears. Helical gears and the efficiency of spiral gears are dealt with in some detail.

The chapter on Governors includes a simple method of dealing with the effect of the masses of the arms and an account of the inertia governor. A new theory is given for the spring-loaded Pickering governor. Balancing is clearly described and primary and secondary balances are explained with worked examples, this chapter concludes with the Fourier series for the acceleration of a piston. Under Friction the author includes some modern illustrations of clutches and ball and roller bearings as well as a description of the Michell thrust bearing.

The general impression is that this book is clear, pleasant, and easy to read. It is expected that it will be of use to engineers and designers as well as students.—A. M. FRANKAU

LUYKEN, W. "*Die Vorbereitung des Hochofenmöllers einschliesslich der des Hochofenkokses.*" 8vo, pp. x + 377. Illustrated. Berlin/Göttingen/Heidelberg, 1953: Springer-Verlag. (Price DM. 37.50)

This book describes the entire field of burden preparation in outline and general principle rather than in great detail. An introductory section is devoted to physical properties of blast-furnace burdens required by modern practice and to the effects on furnace performance of variations of size distribution in the ore.

Iron and manganese ores are dealt with next, covering varieties of ores, ore constituents and compositions, ore sources for German and European consumption, world production, and reserves. A separate chapter is concerned with the costing of iron ore and coke on the basis of metallurgical considerations and on general economic principles. All prices and costs are based on German 1935–1939 figures.

Ore preparation is described under the headings of crushing, screening, mixing, and drying. A major section of the book is devoted to methods of beneficiating iron ores and coking coals. Included are accounts of preliminary laboratory tests, micro-examinations, and methods of assessing the improvements theoretically attainable. A wide range of processes is covered including grinding, classifying, jigging, tabling, log-washing, washing, and sedimentation, also flotation and a brief consideration of de-watering by thickeners and filters. Descriptions of various magnetic separators are followed by a survey of calcining of iron ores with details and brief operating data of several types of calcining kilns. Magnetizing roasting is dealt with more fully and the Krupp-Renn process is described. Applications of heavy-media separation to coal and ore treatment are shown, also uses of the hydrocyclone for classification and de-watering. Electrostatic separation and chemical methods of concentration are outlined.

The second largest chapter of the book is given to the subject of agglomeration. It deals mainly and in detail with the development of sintering, which is discussed in all its aspects. There are also descriptions of briquetting and pelletizing, the latter being regarded as a type of sintering. The addition of ore fines to coal in coke-ovens is reviewed.

A section on economics of burden preparation deals with the economics of ore preparation, concentration, and agglomeration, mostly on the basis of German pre-war figures.

The production and properties of blast-furnace coke are described under the headings of occurrence and properties of coking coals, the coking process, coke properties and statistics. Lime production by calcining is dealt with in brief.

Finally, some examples of industrial installation are provided, including the ore blending plant at the Sophienhütte, Wetzlar, the ore preparation plant at Corby, and the Salzgitter ore preparation plant at Watenstedt, washing plant at Calbrecht, and Krupp-Renn plant at Heerte.

The book should prove a useful and acceptable introduction and general survey of burden preparation to the German student. It will please his national self-esteem because emphasis is placed heavily on German achievement. Much of the information is drawn from German pre-war sources and there is a scarcity of appreciation of important developments which have resulted from a large volume of post-war work carried out outside Germany, particularly in the fields of ore preparation and sintering. Some of the information given is out of date; for instance, the preparation plant at Corby has been greatly modified during the last three or four years.

The omission of much operational detail and facts from practice may have been necessitated by the wide range of aspects covered within 370 pages but it lowers the value of the book to the practical operator. The absence of a collected bibliography proves irksome, but the book will be found useful because it provides the only present-day survey of its subject.—E. COHEN

MILLER, G. L. "*Metallurgy of the Rarer Metals.*" Vol 2—"*Zirconium.*" 8vo pp. [xviii +] 382. London, 1954: Butterworths Scientific Publications. (Price 45*s.*)

The second volume in this series may not be as directly interesting in itself to iron and steel metallurgists as was the first on chromium, and as may be the volumes yet to appear on titanium, manganese, and molybdenum; zirconium is, of course, rapidly becoming a metal of importance in its own right and has removed itself from the class of those elements which are used in minor amounts, but with disproportionate effect, in steelmaking. Production, though precise figures for recent years are not given in Dr. Miller's book, may now amount to several hundred tons per year. The technique of producing pure zirconium is difficult and complicated, and Dr. Miller justly dedicates his book to Dr. W. J. Kroll, a leader in the development of the process involving the reduction of zirconium tetrachloride by magnesium. He also pays full tribute to van Arkel, de Boer, and Fast who, in 1925 by the iodide process, produced a ductile metal showing the true properties of zirconium, and to many other workers from Berzelius onwards. For the rest, Dr. Miller's book is a most valuable compendium of technical information on the properties, extraction, and working of zirconium, going fully into the incessant and complex precautions necessary at all stages of these processes, and including even the safety precautions required in the handling of the metal in powder form, as well as a reference to its low toxicity. It is certain that, however much the production of zirconium may grow and develop, this book will remain a basic text for a long time to come.—J. P. S.

MURPHY, A. J. (Editor). "*Non-Ferrous Foundry Metallurgy.*" La 8vo (x +) 496. Illustrated. London, 1953: Pergamon Press, Ltd. (Price 70*s.*)

This book, of which Professor Murphy is the editor, though it bears the sub-title "*The Science of Melting and Casting Non-Ferrous Metals and Alloys.*" and covers foundry practice in the alloys of aluminium, copper, magnesium, nickel, zinc, and so on, nevertheless contains a great deal of interest to the ferrous metallurgist. For example, there are useful chapters, of general application, on the properties of liquid metals (by D. C. G. Lees), on the solution of gases in liquid metals (by the same author) and the solidification of metals (by W. A. Baker). Even the section on non-ferrous foundry technique contains information of value on refractory materials (by J. E. Garside) and on melting furnaces (by the same author) whose usefulness is not wholly confined to the non-ferrous trade. There is, equally, much of general interest in the section on the properties and

testing of castings, notably on the parts on the measurement of gas-content (by C. E. Ransley) and on non-destructive testing (by Otto Vaupel). The book is extremely well produced, tables, illustrations, line-drawings, and lists of references are copious, and speaks well for the industry of Professor Murphy and his distinguished collaborators ; one's sole complaint is that the names of the latter are not to be found on the title page or in the general contents list, but only at the heads of the chapters or sections for which they are responsible.—J. P. S.

RIGBY, G. R. "*The Thin-Section Mineralogy of Ceramic Materials.*" 2nd Edition. With a Foreword by A. T. Green. 8vo, pp. 231. Illustrated. Stoke-on-Trent, 1953 : The British Ceramic Research Association. (Price 32*s.* 6*d.*)

This, the second edition of Dr. Rigby's monograph is substantially the same as the original version but includes some additional material. To the opening section on the preparation of thin sections has been added details for the production of polished thick (and thin) sections for examination by reflected light. The methods and apparatus are clearly described and cover many useful hints worked out in practice, one of the neatest of which is the use of home-made plastic-impregnated polishing discs. More use could have been made of diagrams to illustrate the differences in equipment, and the very fast method of grinding directly to almost final thickness by means of a peripheral diamond has been ignored. In view of the excellent photographs of polished sections introduced at the end of this edition it seems a great pity that some description of photographic apparatus and techniques has not been given.

The need to use these methods, together with optical properties measured on mineral fragments, and X-ray and chemical analysis to supplement each other is brought out. The main advangage of the polished specimen is the power to see texture clearly even at very high magnification rather than as a means of phase identification on its own.

The chapter on the microscope clearly differentiates the useful from the ornamental gadgets, and indicates the real ways in which some modern microscopes have improved on pre-war models.

The next subject considered is the optical properties required for identification and the methods of measurement. This is excellently done though a minor improvement to help the beginner might be to make it possible, by the use of a different type, readily to pick out the descriptions for actual manipulation from the theoretical.

To the collected data on the optical properties of minerals fifty more have been added, including some on borides and sulphides, but data on the silicides are not yet included.

The data are more scanty in some sections than in others. The classification is a little illogical, due mainly to grouping some materials under raw materials and others under artificial minerals, merely according to whether or not they happened to be examined in processed materials. The name and formulæ indices do much to offset this disadvantage. In addition to the optical properties, melting points are given in many cases, and useful snippets of information are to be found in the sections marked occurrence.

The book is attractively bound and clearly printed, and it should repeat the success of the earlier edition.

W. A. ARCHIBALD

VAN SANTEN, G. W. "*Introduction to a Study of Mechanical Vibration.*" With a Foreword by B. E. Noltingk. Translated into English by G. Ducloux. 8vo, pp. xvi + 296. Illustrated. Eindhoven (Holland), 1953 : N. V. Philips Gloeilampenfabrieken.

This book, a translation from the Dutch, is a welcome addition to the series of technical works issued by N. V. Philips Gloeilampenfabrieken (Eindhoven).

The subject of mechanical vibration is very wide, covering as it does diverse phenomena and a vast range of frequencies. This book is neither a complete reference work to the whole field nor a specialized account of particular aspects, but rather an introduction touching upon the various branches and emphasizing their common ground. It will appeal to the general worker in engineering and physics who is suddenly confronted with a vibration problem, and the latter chapters will be particularly helpful to the experimental investigator. The list of chapter headings shows a well-planned framework. Few criticisms can be levelled at the scope or the order of presentation. There is some confusion in the opening chapter between vibration of a point and vibration propagation which could have been avoided by omission of any mention of the latter until the chapter on wave motion. Also, more attention might have been given to general methods of calculating the natural frequencies of systems with several degrees of freedom. An account of Rayleigh's energy method is certainly not beyond the scope of a book of this nature.

The reviewer considers that in its original language the book is probably delightfully readable, but the unfamiliarity and multiple use of some of the symbols makes it at times confusing to an English reader. The otherwise excellent translation of the text is spoilt by only a few unusual expressions. The use of "$1\frac{1}{2}$ sines" instead of "$1\frac{1}{2}$ sine waves" on page 103, and "air layer" instead of "boundary layer" on page 121 were noted. There are several inaccuracies liable to confuse the reader new to the subject ; for example, the right hand side of equation 53 is not dimensionally consistent, but is only an approximate formula applicable to a particular system of units. Also the legend of Fig. 69 should surely read "Decreasing (not increasing) speed of propagation". Such errors can of course be easily rectified. The chapters dealing with the practical investigation and measurement of vibration are excellent.—N. C. LAMBOURNE

"*The Wire Industry Encyclopaedic Handbook*, 1954." 8vo, pp. 492. Illustrated. London, 1954 : The Wire Industry Ltd.

The chief additions to the 1954 edition of this useful compilation are a trade summary for 1953, a section of thirty pages on "Branded Names for Wire, Wire Machinery, etc.", a list of American wire specifications, and the extension of the table of translations of "wire-terms" by a large number of entries as well as by three new languages, German, Dutch and Swedish. These will all make the volume still more useful to those in the wire industry.

J. P. S.

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